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LX200 SCHMIDT-CASSEGRAINS

The largest-selling serious telescopes in the world.

Now you can buy the most advanced 8" and 10" Schmidt-Cassegrains ever produced, at a price directly competitive with other SCT's offering only a fraction of the features!

Meade LX200 SCT's offer a revolutionary departure from any other SCT's ever made available. Consider the **standard specifications** of these telescopes:

New Heavy-Duty Fork Mounts—The largest, most rigid in the industry. *Meade 8" and 10" LX200 fork mounts yield the lowest damping times of any SC fork mounts available.* Large 4"-diameter polar ball bearings complemented by DC-servo-motor-driven worm gears on ***both*** telescope axes permit observatory-level precision in tracking, guiding, and slewing.

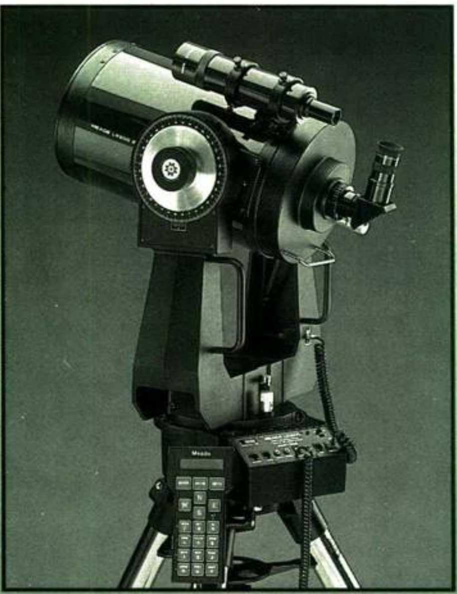
100% Computer-Controlled Operation—All-new Meade LX200 microprocessor-controlled drive systems offer an incredible array of features:

- **Four-speed operation on both telescope axes** simultaneously, including (a) photo-guiding (at **2x** sidereal rate); (b) image centering and microslewing in the main telescope (at **32x** sidereal rate); (c) image centering in the viewfinder (at **2°** per sec.); or fast-slew of the main telescope across the skies (at **8°** per sec.).
- **Pushbutton Electric Slew**—Press RA or Dec slew, east or west, north or south, and the telescope moves at 8° per sec. on both axes. As you near a desired object, flip to 2° per sec. slew, to center the object in the field. The observer need never touch the telescope in moving from one object to another. (Of course, if you wish, the telescope may be moved manually as well.)

Current (mA x 100)
MEADE LX200
COMPUTER DRIVE SYSTEM
LX QUARTZ - DC SERVO MOTOR
SMART DRIVE
On
Off
N
S
Encoders
RS232
Focuser
Reticle
Keypad
Power 12 VDC
CCD

- **Digital Readouts** on both axes, read from the handheld Electronic Command Center (ECC).
- **GO TO Capability**—Enter the RA and Dec of an object into the keypad of the ECC, press GO TO, and the telescope automatically slews to the object at 8° per sec., centering it in the field.
- **747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, polar reference stars), or one of the 8 planets, from Mercury to Pluto, press GO TO, and the telescope slews at 8° per sec. to the object with uncanny precision. For $99* add the 8000-object Meade CNGC library, a 30-second plug-in.
- **Permanently programmable (PPEC) Smart Drive**™, capable of reducing periodic drive errors to 5 arc. sec. or less.

Legendary Meade Super Multi-Coated f/6.3 or f/10 Schmidt-Cassegrain Optics—Now you can choose either wide-field f/6.3 or classical f/10 Meade US-made SC optics **at the same price.** Either way, you'll be buying the finest Schmidt-Cassegrain optical system available, a system that yields razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space, from the World's leading manufacturer. Meade exclusive Super Multi-Coatings on both sides of the correcting plate assure maximum light transmission and contrast.



Altazimuth Mode Operation—For all visual observing applications, and for lunar and planetary photography, Meade LX200's may be set up in the altazimuth mode, without any equatorial wedge—just attach the telescope's drive basé directly to the tripod, use the fast 1-star alignment procedure, and the telescope's computer actuates 2-axis tracking that keeps objects precisely centered in the field, even at high powers, during the entire observing session. For long exposure photography (longer than about 5 minutes) altazimuth-induced field rotation requires an equatorial wedge, which may be purchased separately.

Fast Polar Alignment—Center two reference stars in the telescopic field and the telescope's computer tells you exactly what telescope controls to actuate for precise polar alignment in the equatorial mode in less than a minute.

The widest array of keypad and power-panel control functions—In addition to the microprocessor-controlled operations listed above, the handheld ECC and the telescope's power panel permit: readout of sidereal or local time; actuation of the optional electric focuser; crossline brightness control of an illuminated reticle eyepiece; direct plug-in of popular CCD autoguiders/imagers; and more than 14 other telescope functions.

MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

- Handheld Electronic Command Center—With 2-speed operation, **2x** for photo-guiding and **32x** for image centering and microslewing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)
- Permanently programmable (PPEC) Smart Drive, as described above.

Complete LX100 and LX200 Telescopes

Specifications: 8" and 10" LX200's—Each complete telescope includes: 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount, with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld keypad Electronic Command Center, with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cords for telescope operation from either 12 v. DC auto cigarette lighter plug or 115v.AC; 8 x 50mm viewfinder with crosshairs; diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece; variable-height field tripod; new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

Specifications: 8" and 10" LX100's—Each complete telescope includes 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, 5.75" RA worm gear, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld pushbutton Electronic Command Center with PPEC Smart Drive and 2-speed drive control; 25 ft. power cords for telescope operation from either 12v. DC auto cigarette lighter plug or from 115v. AC; viewfinder: 6 x 30mm (8") or 8 x 50mm (10"); diagonal prism (1.25"); Series 4000 Plössl 26mm eyepiece; variable-height field tripod; equatorial wedge (8") or Superwedge (10"); new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

For the beginner, or for the most seasoned observer, Meade LX200's are the most user-friendly telescopes ever manufactured. First-time telescope users **almost uniformly** remark that "I saw **hundreds** of deep-space objects my very first night out!" Advanced amateurs report that "the LX200 found objects during my first observing session that I was unable to locate in over 20 years of serious observing with other telescopes."

Contact your authorized Meade dealer today. See for yourself why Meade LX200's are the largest-selling serious telescopes in the world.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
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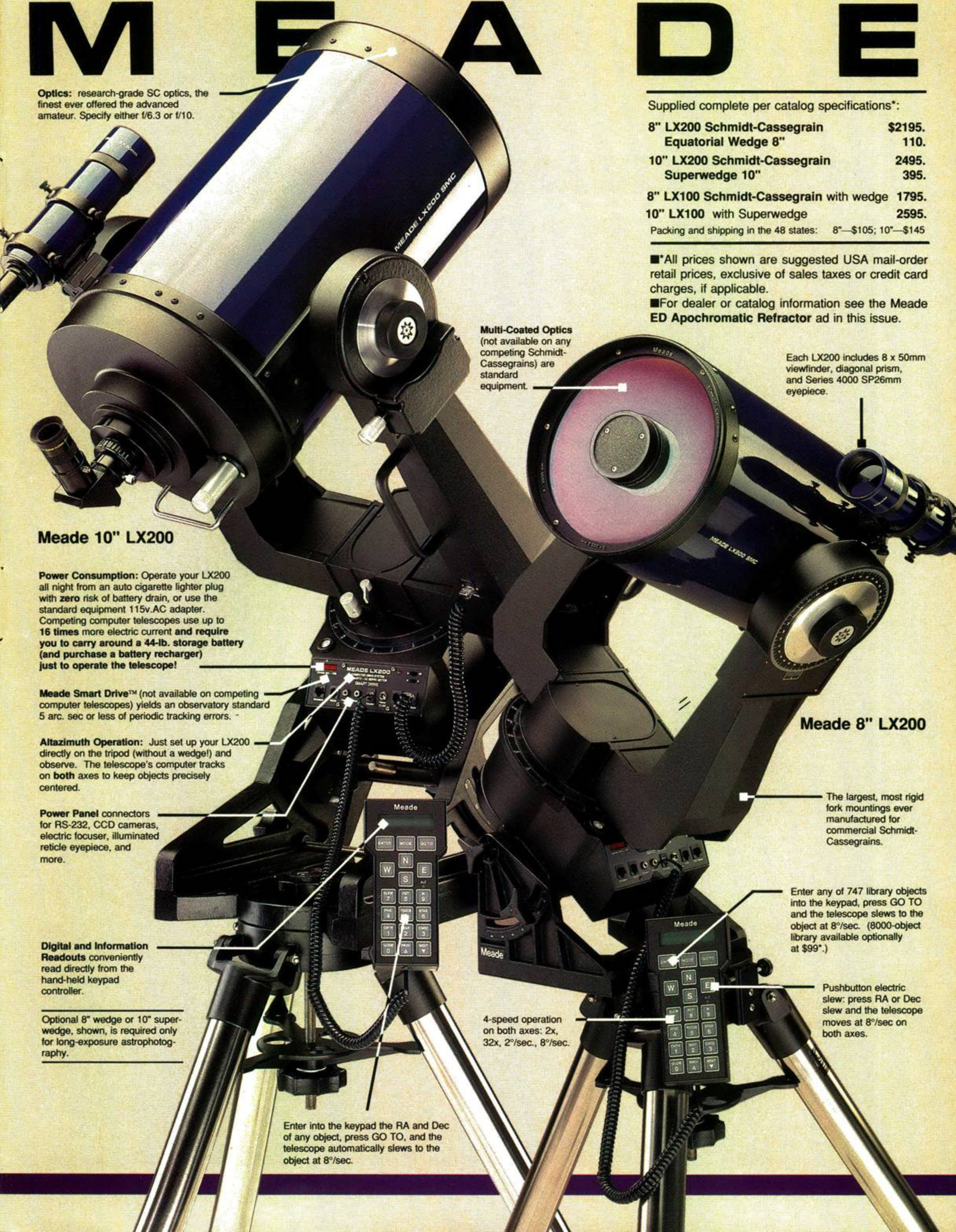

Optics: research-grade SC optics, the finest ever offered the advanced amateur. Specify either f/6.3 or f/10.

Supplied complete per catalog specifications*:

8" LX200 Schmidt-Cassegrain	**$2195.**
Equatorial Wedge 8"	**110.**
10" LX200 Schmidt-Cassegrain	**2495.**
Superwedge 10"	**395.**
8" LX100 Schmidt-Cassegrain with wedge	**1795.**
10" LX100 with Superwedge	**2595.**
Packing and shipping in the 48 states:	8"—$105; 10"—$145

■*All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

■For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.

Multi-Coated Optics (not available on any competing Schmidt-Cassegrains) are standard equipment.

Each LX200 includes 8 x 50mm viewfinder, diagonal prism, and Series 4000 SP26mm eyepiece.

Meade 10" LX200

Power Consumption: Operate your LX200 all night from an auto cigarette lighter plug with **zero** risk of battery drain, or use the standard equipment 115v.AC adapter. Competing computer telescopes use up to **16 times** more electric current **and require you to carry around a 44-lb. storage battery (and purchase a battery recharger) just to operate the telescope!**

Meade Smart Drive™ (not available on competing computer telescopes) yields an observatory standard 5 arc. sec or less of periodic tracking errors.

Altazimuth Operation: Just set up your LX200 directly on the tripod (without a wedge!) and observe. The telescope's computer tracks on **both** axes to keep objects precisely centered.

Power Panel connectors for RS-232, CCD cameras, electric focuser, illuminated reticle eyepiece, and more.

Digital and Information Readouts conveniently read directly from the hand-held keypad controller.

Optional 8" wedge or 10" superwedge, shown, is required only for long-exposure astrophotography.

Enter into the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8°/sec.

4-speed operation on both axes: 2x, 32x, 2°/sec., 8°/sec.

Meade 8" LX200

The largest, most rigid fork mountings ever manufactured for commercial Schmidt-Cassegrains.

Enter any of 747 library objects into the keypad, press GO TO and the telescope slews to the object at 8°/sec. (8000-object library available optionally at $99*.)

Pushbutton electric slew: press RA or Dec slew and the telescope moves at 8°/sec on both axes.

ON THE COVER: Glowing clouds of hydrogen gas in the shape of North America punctuate the Milky Way in Cygnus. While early risers get a jump on summer's best sights, other exciting targets await you in the evening. For the best April has to offer, see Sky Almanac on page 46. Photo by Tony Hallas and Daphne Mount.

EARTH'S DARK SHADOW covered the Moon on December 9, leaving just a hint of orange-red on the surface of the eclipsed Moon. See Reader Reports on page 81 for more on this outstanding eclipse.

Ken Spencer

20th ANNIVERSARY YEAR

ASTRONOMY

April 1993

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The Audit Bureau

Behind the Scenes

ROCKS IN OUR HEADS

The solar system threw a rock at Earth last December and nobody noticed. Well, that's not quite right. It's true the general public heard little about the event, but lots of planetary astronomers, amateur and professional, did take notice. The "rock" in question was the asteroid 4179 Toutatis, and you can see some results of its flyby on pages 36 and 37.

Guided by starcharts in December's Sky Almanac, many ASTRONOMY readers took their telescopes out for a look at this object. Through a scope you couldn't see a lot. Toutatis was a faint dot of light that moved noticeably over the course of a few minutes or hours. The thrill for most observers lay in finding and following this hurtling piece of real estate as it pursued its lonely path around the Sun. In your imagination at least, you could fly along as it shot past Earth at 10 times the Moon's distance.

But what an interesting object it turned out to be. Not one chunk of rock, but two, rotating slowly and nestled together like a gigantic peanut. You look at the radar pictures of Toutatis and one thing's clear: asteroids are like aged prize fighters, longtime dwellers in the world of hard knocks.

Scientists are calling Toutatis a "contact binary" asteroid. It is made of two rockballs that have crunched together so gently that each still preserves a basic rounded shape. Toutatis is not the first contact binary asteroid to be discovered. About four years ago, JPL astronomer Steve Ostro made radar observations of an object then designated 1989 PB. Although its radar images weren't as detailed as those of Toutatis, 1989 PB (since renamed 4769 Castalia) showed a distinct two-lobed structure. And over the years numerous other asteroids have also been suspected of being binary.

No one has yet seen any of these other binaries clearly — like every asteroid, they're just points of light in an eyepiece. But, thankfully, in the last couple of years asteroids have begun to come in from the dark. Galileo gave us a look at 951 Gaspra and revealed a smoothly contoured, highly irregular object wrapped in a thin mantle of dust and pocked by craters. 243 Ida is next, to be visited by Galileo this August as the craft threads through the asteroid belt on its way out to Jupiter.

But Ida won't mark an end to asteroid exploration by spacecraft. The Defense Department's Clementine probe will fly past 1620 Geographos in August 1994, marking the first-ever encounter with a near-Earth asteroid. Also, under NASA's Discovery program for low-budget (under $150 million) missions, planetary scientists are preparing many proposals to send small instrument packages to other near-Earth asteroids. Further, NASA intends (costs permitting) to send every craft bound for the outer solar system past at least one main-belt asteroid on its way.

Do planetary astronomers have rocks in their heads? You bet, and it's about time.

Sincerely,

Robert Burnham
Editor

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Letters

Funds Available for Education Projects

During 1993-94 the V. M. Slipher Committee of the National Academy of Sciences will have a modest amount of funds ($4,500) to support projects that enhance the public's understanding of astronomy. Preference will be given to projects requiring seed money for programs that will continue beyond the funding period. Past grants have included support for radio programs on astronomy, refurbishment of an historical telescope for public use, and support of teacher workshops and park interpretive programs. Applications should outline the project's objectives, budget, and other sources of funding. Proposals should be no longer than 3 typewritten pages. Applications, postmarked no later than May 17, 1993, should be sent to Dennis Schatz, Chairman, V. M. Slipher Committee, Pacific Science Center, 200 Second Avenue North, Seattle, WA 98109.

Project ASTRO Needs You

Project ASTRO is a new project in astronomy education at the Astronomical Society of the Pacific. Funded by the National Science Foundation, the program is designed to explore the potential for amateur and professional astronomers to visit 4th- to 9th-grade classrooms and help get students excited about astronomy and science. As part of the first phase, we'd like to hear from astronomers, both amateurs and professionals, who have conducted such visits. We would like them to fill out a brief questionnaire and help advise us on what went well and not-so-well during their visits. If you can help out, please call (415) 337-1100, fax (415) 337-5205, or write to Andrew Fraknoi, c/o Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

Watching Stars Move

I have been measuring multiple star systems for a decade now with micrometers of my own manufacture. When I got the November 1992 issue I went right to the article "Autumn's Colorful Double Stars" by Mark T. Stauffer. I was glad to see 61 Cygni on his list of finer double star systems, but the author didn't mention the pair's proper motion across the sky (some 5.5 arcseconds per year). If you take the time to sketch the field surrounding this star, you will notice this pair's movement with respect to the nearby stars in only a couple of years.

Epsilon Equulei is only a mediocre

[continued on page 12]

Perhaps the greatest of all astronomers, Galileo met with scorn and indifference in his own time. But thanks to the EPOCH 2000™ Desktop Observatory, being a great astronomer today is much easier. This remarkable program enables you to explore a vast universe beyond even Galileo's dreams.

When installed on a PC running Microsoft® Windows,™ EPOCH 2000 allows you to perform many of the same sophisticated exploration techniques professionals use.

With power and accuracy that rivals mainframe computer performance, EPOCH 2000 is actually three programs in one:

DESKTOP PLANETARIUM. EPOCH 2000 displays the sky from 4713 BC to 10000 AD – over 45,000 stars, 7,500 asteroids, 600 comets and more than 13,000 deep sky objects, including the complete NGC, IC and Messier catalogs. If you have a CD-ROM drive you can access another 20 million stars from the Hubble Guide Star Catalog.* The program also lets you measure the distance between stellar objects, and determine each star's magnitude, color and spectral class.

EPOCH 2000.™
ENJOY MORE
ASTRONOMICAL
SUCCESS IN AN
EVENING THAN
GALILEO
DID IN
A LIFETIME.

IMAGE PROCESSING. EPOCH 2000 allows you to analyze and enhance high resolution CCD images. You'll bring out hidden details in planets, moons, stars, nebulae and galaxies using advanced techniques such as dynamic scaling and histogram equalization. Plus, our exclusive RGB Merge feature lets you produce true full-color images.

REMOTE TELESCOPE CONTROL. EPOCH 2000 gives you the capability to control a Meade LX200 or ED-APO telescope from your PC. And it can also support the SBIG ST6 CCD camera, allowing you to remotely capture images from the comfort of your own home.

Whether you're a hobbyist, serious amateur or professional, let EPOCH 2000 bring out the great astronomer in you.

For more information call (800) 858-9795.

*Purchased separately.

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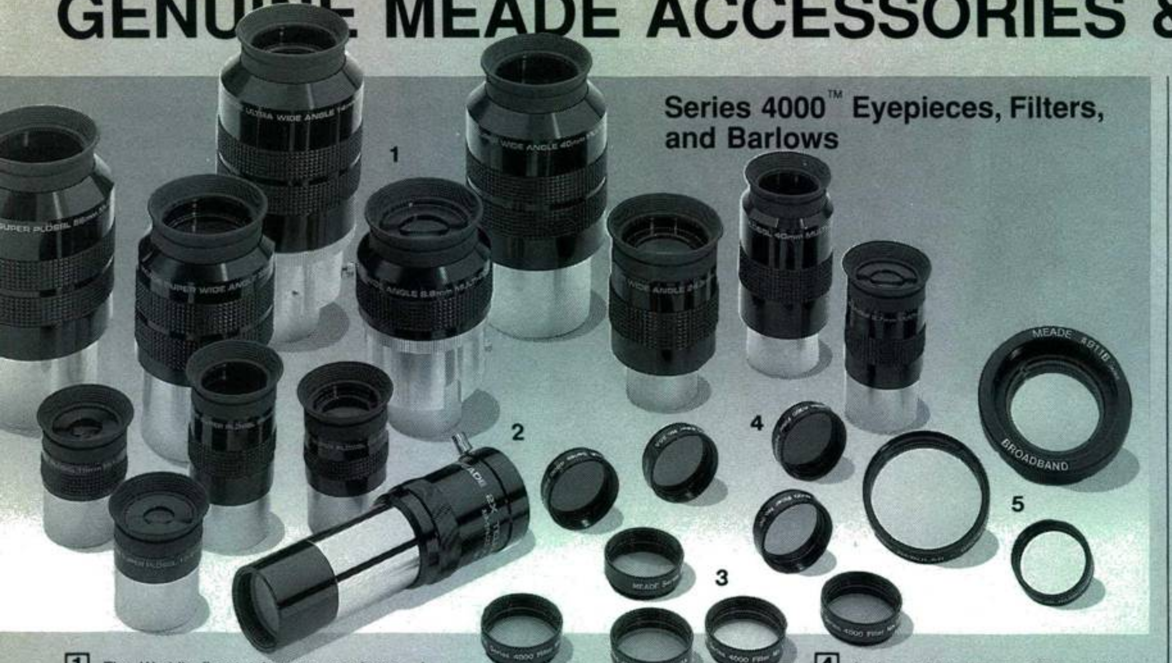
Series 4000™ Eyepieces, Filters, and Barlows



1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$87.95** (3.29)
32mm(52°); 40mm(44°); each **109.95** (3.79)
56mm (52°, 2") **229.95** (4.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm: **139.95** (3.29) 18mm: **149.95** (3.29)
24.5mm: **169.95** (3.79) 32mm(2"): **239.95** (4.18)
40mm(2"): **299.95** (4.18)

Ultra Wide Angles (8-elements, 1.25"; 84°):
4.7mm: **154.95** (3.29) 6.7mm: **187.95** (3.29)
8.8mm(1.25"/2"): **229.95** (4.18)
14mm(1.25"/2"): **269.95** (4.18)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$79.95** (3.29)

3 **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets . Thread into virtually all 1.25" eyepieces sold today. Fully coated.
#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.
each **$12.95** (2.29)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$49.95** (2.79)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$49.95** (2.79)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green **$49.95** (2.79)

Sets #1 & #2—8 filters **$89.95** (3.29)

Sets #1, #2, & #3—12 filters **$129.95** (3.48)

4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$15.95** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

BROADBAND FILTERS

#908B (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$79.95** (2.49)

#910B—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.79)

#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **99.95** (3.29)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (2.49)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **129.95** (2.79)

#911N--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **119.95** (3.29)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25" **$129.95** (3.29)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$109.95** (3.29)

MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$94.95** (3.29)

MA 12mm—Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$74.95** (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

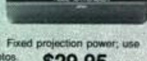
Camera Adapters (1.25" & .965")

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.
.965": **$27.95** (2.79) 1.25": **$29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.79)

Tele-Extenders



For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$39.95** (2.79)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera. **$26.95** (2.79)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

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#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (3.29)

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Rack-and-Pinion Focusers (2")

#680--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **99.95** (3.78)

#682—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.78)

Viewfinders: 30mm, 50mm, 60mm

#637: 6 x 30mm–Fine, 7° wide-field finder; coated, achromatic lens; crosshair eyepiece. 2-ring bracket with alignment screws. Attaches to tube diameters 6" to 12" **$49.95** (3.29)

#545: 8 x 50mm– *(lower photo)* Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below. **69.95** (4.28)

#544: 8 x 50mm– Same as #545, but in Meade blue. **69.95** (4.28)

#957: 9 x 60mm—*(top photo)* Collects 44% more light than 50mm; superior for faint objects; bracket below. **99.95** (4.68)

Bracket for 8 x 50mm: Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **17.95** (2.79)

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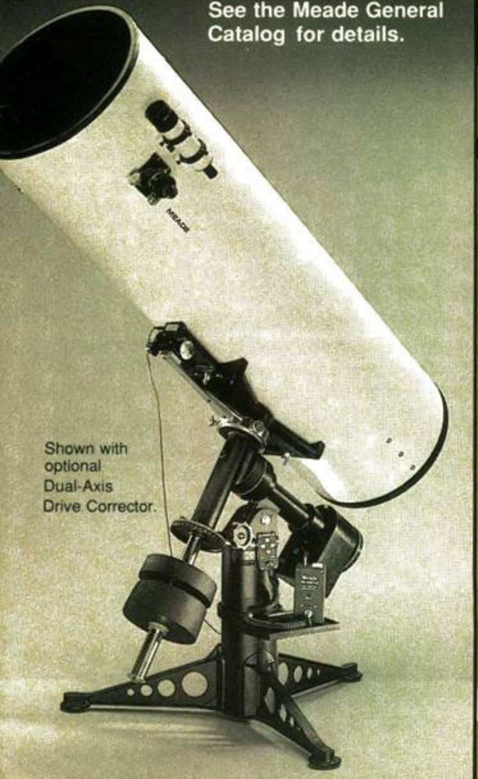

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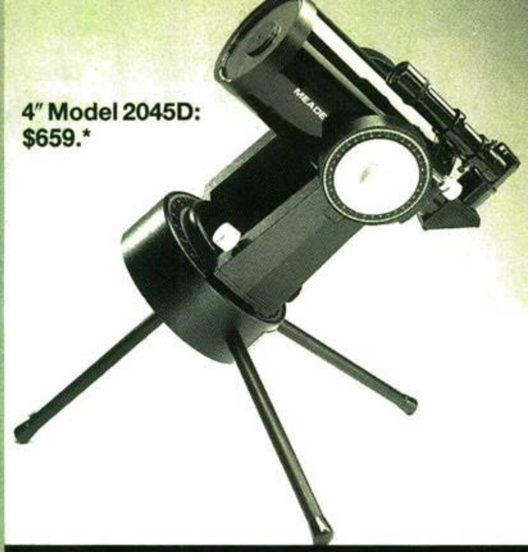

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Model 2080B—Identical to Model 2080A, but in addition with Super Multi-Coated optics. .... **$1149.**

Packing & shipping on either 8" model in the 48 states: . **$95.**

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Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7″ rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2″ diagonal mirror, and Super Plössl 26mm eyepiece:

4″ f/9 Model 102ED, complete	**$1995.**
5″ f/9 Model 127ED, complete	**2495.**
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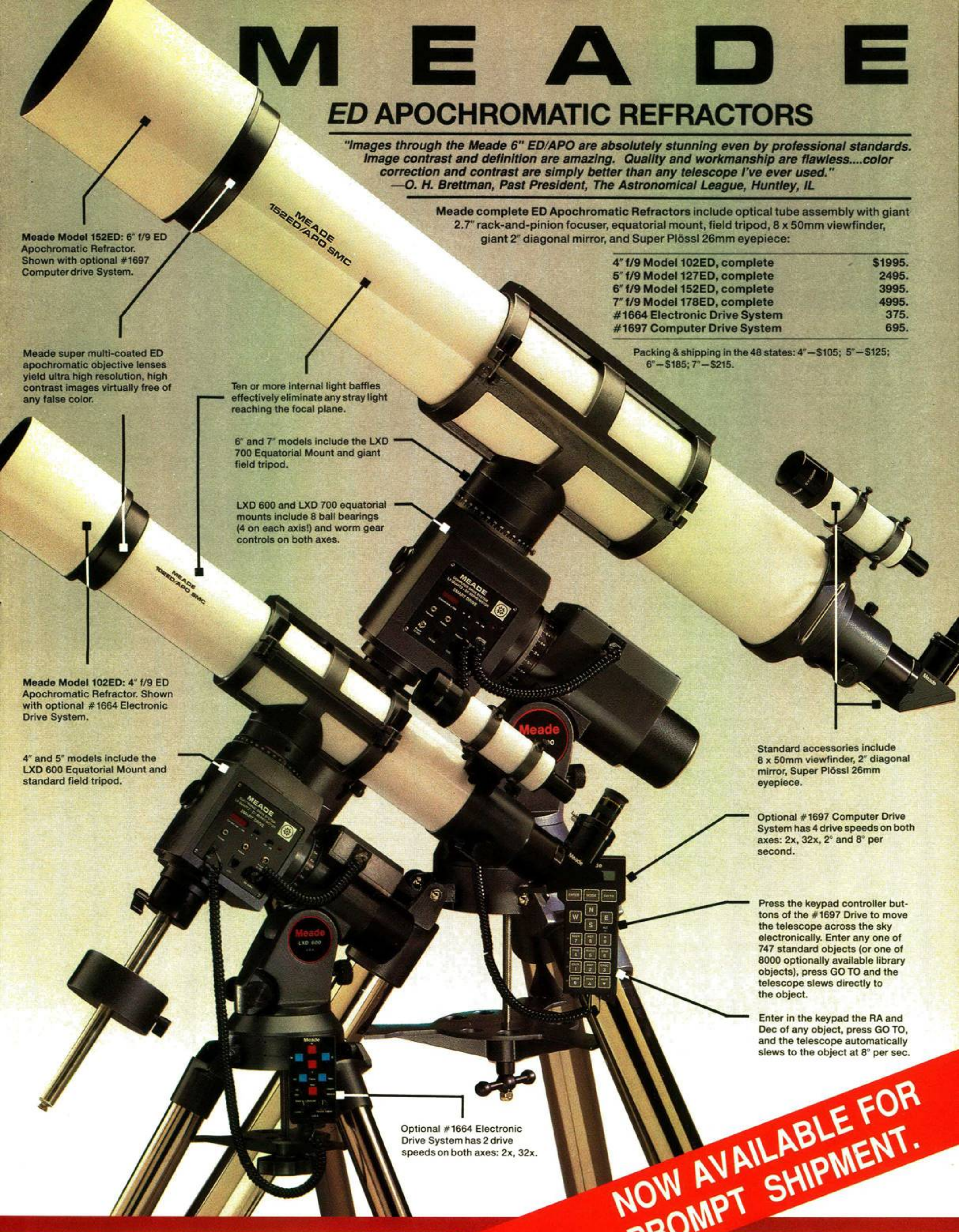
#1664 Electronic Drive System	**375.**
#1697 Computer Drive System	**695.**

Packing & shipping in the 48 states: 4″—$105; 5″—$125; 6″—$185; 7″—$215.



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Meade super multi-coated ED apochromatic objective lenses yield ultra high resolution, high contrast images virtually free of any false color.

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LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis!) and worm gear controls on both axes.

Meade Model 102ED: 4″ f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4″ and 5″ models include the LXD 600 Equatorial Mount and standard field tripod.

Standard accessories include 8 x 50mm viewfinder, 2″ diagonal mirror, Super Plössl 26mm eyepiece.

Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

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double star but under high magnification the brighter star splits into nearly equally bright components. The pair has an orbital period of 101 years — in one year the stars revolve an average of 3.5°. Again, by making careful drawings, it is possible to detect this orbital motion in only a year.

With modest equipment you don't need to simply look at these stars — you can add a new level of experience and look for change in the stars, be it orbital or proper motion. — *Richard Hill, Tucson, Arizona*

Imagining Other Solar Systems

Recent reports of planet detections around other star systems got me curious enough to calculate how big planet orbits around nearby stars would appear in a telescope. I wanted to compare their size to the size of the diffraction rings seen around bright stars when viewed at high power in a good or stopped-down telescope.

If you look at Sirius (9 light-years away) with a 3-inch telescope, the first bright diffraction ring is about 12 astronomical units across and the second fainter ring is about 20 AUs across. This means these rings trace out the orbits of the equivalents of Jupiter and Saturn around Sirius. For Alpha Centauri at 4.3 light-years away, the diffraction rings for a 10-inch telescope correspond to the orbits of Earth and Mars. — *Donald G. Bruns, Colorado Springs, Colorado*

Shifting Your Optics

I really enjoyed "Taking Pictures with Your Telescope" in the December 1992 issue. The illustrations leave the reader with the impression that photography can be done with all Newtonian reflectors "off the shelf." This is often not the case. In some models, the focuser can't be racked in far enough to form an image at the film plane of a typical 35mm camera body. In these cases, the primary mirror has to be moved forward an inch or so or the focuser reduced in height the same amount. Some Newtonians with low-profile focusers allow the use of a camera as is. — *Ed Morrell, Regina, Saskatchewan*

The Urban Astronomy Movement

Hooray for Ron Pommier's Viewpoint in the December 1992 issue about city astronomy. Millions of children may never get outside a city environment. Each one of them should be given the chance to see the stars, planets, and other wonders above their heads.

I urge all you casual and serious amateurs out there to please not promulgate the idea that astronomy is an exclusive, elitist hobby but to share some of your basic knowledge. The reward in city astronomy comes from focusing on things you *can* see. — *Christine M. Roane, Springfield, Massachusetts*

Observing Breakthrough Supported

After reading about Dean Grantham's breakthrough in amateur astronomy observational techniques (Viewpoints, January 1993), I hastened to duplicate his procedures. While I can heartily endorse his approach, I found a few minor problems inherent with it. For example, it seems that amateur astronomers cannot actually study a celestial phenomenon until after it has occurred, undoubtedly due to a peculiar form of relativistic time dilation in Grantham's proposed CMYK model of the universe. It seems that the span of time between actual discovery and the ability to use this technique is roughly three months. — *Wayne Wyrick, Oklahoma City, Oklahoma*

I was so intrigued by Grantham's findings of "universal granularity" that I had to see for myself. Since it was just before Christmas, I set up my first object (variable star Iss. May 92 P.N. 70-71) next to the Christmas tree for illumination and placed the telescope just outside the opened back door. By golly, to my disbelief I could actually see the star varying. Not only in magnitude but also in apparent color: green, yellow, blue, red, orange, and combinations of all. After several hours of observing I could not pin down a predictable cycle. Thank you for leading me into such a fascinating new field. Maybe I will sell my clock drive for a down payment on a spectrometer. — *James Rayner, Carson, California*

I have tried Dean Grantham's observational technique, but have often been puzzled by the occasional appearance of 2 or 3 pairs of bright linear features that sometimes appear when an object being studied is in the center pages. Each pair is aligned with the others in a straight line. Could these be lensing features or perhaps jets? — *Terry Mosely, Glengormley, Northern Ireland* ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187-1612. Letters may be edited for length and clarity.

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INSECURITY LIGHT

by Peter Leschak

I'm tempted to blow away a streetlight. I know I won't, really. My veneer of civilization is thick enough, and vandalism probably wouldn't extinguish the bulb permanently anyway.

But I sure fantasize: slipping out some January night when the glaring fixture pours its harsh illumination on falling snow. I picture the hit — a satisfying explosion of glass followed by darkness — as going down at 2 or 3 a.m., when absolutely no one is around.

Of course, there's never anyone around that light anyway. For half a century the intersection remained dark, no one bothering to light up the road, the aspen grove, and the ash swamp.

I was at the township board meeting six years ago when they decided to install that light. A certain citizen, not seen at a board meeting before or since, insisted that for public safety a streetlight should be put in at that particular intersection. The board agreed to request a light from the local electric co-op. Who could oppose public safety? But afterward I heard wry comments about the citizen's motives. Some said the man was less concerned about the public than he was about missing his turn and ending up in the ditch when he came home from town half-bagged.

The light appeared and soothing darkness was banished from another cranny of the woods. The power company calls them "security lights" and seems eager to hook up as many as possible. It will even give you a flat rate so you'll feel free to leave yours on all night. Indeed, photocells automatically switch on most of the lights at dusk. What a curious practice in an age of conservation! As more people move out from town to live in our remote backwoods township, security lights blaze their trail. Rare is the newcomer who can resist the impulse to bathe the property in electric mist. They all want to make their homestead look as much like a city address as possible.

Where's the security? If I were a burglar, the houses I'd go for are those all lit up with "security" lights. How better to discover certain important things: Is there a Doberman snoozing on the porch? Where'd the kids leave the wagon and trike? Has the mark got anything outside worth swiping? Are any windows unblocked? Yes, I'd call the light a help. And there'd still be plenty of deep shadow to hide in, made all the deeper by contrast. Why risk sneaking into a pitch-black yard when the neighbor is dumb enough to leave his all lit up?

When I was small, I had to sleep with a light on in my room. I was afraid of the boogeyman. But I finally began to sleep in darkness when a friend convinced me that a light just let the boogeyman get a better look at me.

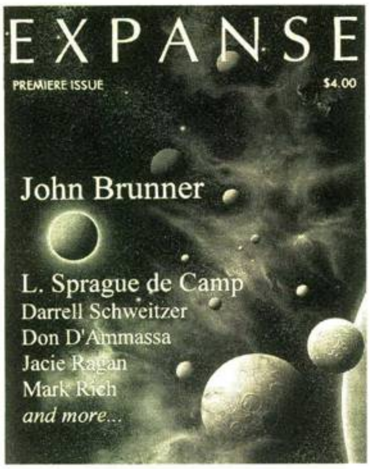
Our security lights are symbols of fear and distrust, of one-sided notions of night as evil and menacing. Darkness can conceal, but it's also liberating and revelatory. If a portion of our planet were never in shadow, our cosmos would be a minuscule patch of sunlit ground. We'd be unaware of star clusters and galaxies — ignorant of the wondrous expanse of universe. Our perspective would be fully lit but painfully small.

Are we afraid of open space? Is that why so many deliberately seek to destroy the night? Even when they have no reason to fear muggers, thieves, or prowlers? Isn't a backwoods intersection lit more than adequately by the sweep of our car headlights? Why shed constant light on a stretch of road that's vacant more than 99 percent of the time? I suspect our reason transcends practicality and touches a deeper fear.

"In dark time," wrote the poet Theodore Roethke, "the eye begins to see." Because in darkness is a new world, a planet turned away from its star, where the many daylight images and distractions are tempered by shadow. We know our true status only at night, as our pupils expand to let in the cosmos.

Back in the 1960s, Simon and Garfunkel had a smash hit with their song "The Sounds of Silence." Remember how it began? "Hello, darkness, my old friend. / I've come to talk with you again." It suggests a communing with the night that I find irresistible. There's no greater stimulus to reflection than strolling a country road under a dark sky with constellations framed by trees. I feel less a pure Earthling and more a citizen of the Galaxy. I sense the presence of spacetime, anointed by starlight that has traveled for eons. I feel more powerful then — and not overwhelmed by the bright

[continued on page 17]



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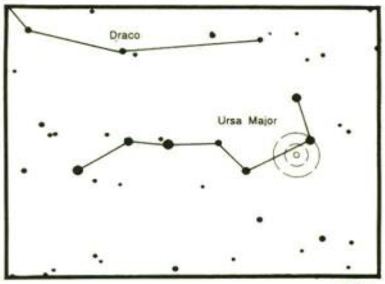

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17
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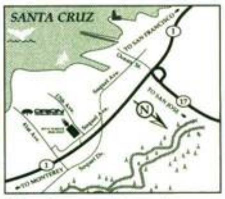

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If you are thinking about buying a Celestron telescope, Orion is the place to buy it. We've sold thousands of Celestron telescopes to amateur astronomers across the USA. Our low, low prices and special accessory packages can really save you a bundle! Whether you are considering a big telescope or a small one, or a binocular or accessory, chances are Orion has just what you are looking for. And we probably have it in stock for immediate delivery, too!

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Incredible wide field eyepiece design, Fully Multi-Coated, BAK-4 prisms, and best special glass objective lenses make the 7x50 Adlerblick the arch rival of European brand binoculars selling for 3-4 times the price. Orion buys direct, saving you money. Includes deluxe hard case, lens caps and straps.

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56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Standard model 33 oz. Rubber Armored for protection from bumps. Weighs 37 oz.

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The standard for hand-holdable astronomy binoculars. Fully Multi-Coated. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

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NEW! 10x70 Waterproof Binoculars

Light enough to hand hold, yet powerful enough to bring in remarkable views of deep space celestial objects. With military-grade optics, for the highest degree of optical accuracy and mechanical ruggedness. Will last through a lifetime of use, even under the most extreme environmental conditions. Absolutely waterproof and fogproof. With built-in folding rubber objective lens shades/dew caps. Includes deluxe case, photo tripod adapter. 7mm exit pupil. 5° field of view. #9309 ***$444*** (7.29)

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NEW! Orion 70° MegaVista 2" Eyepieces

These new 2" eyepieces offer incredible sharpness to the edge of the wide 70° field. The 7-element design and fully multi-coated optics ensure maximum image contrast and freedom from ghosting. The extra-long eye relief and foldable rubber eyecups make it easy to locate the proper viewing distance—ideal for eyeglass wearers. Compare these new MegaVistas to much more expensive brands—you're sure to be impressed!

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40mm #8588 **$229** (3.45)

Explorer .965" Eyepieces

Fine quality Multi-Coated eyepieces.

.965" Orthoscopic 5mm #8580, 7mm #8581, 9mm #8582, 12.5mm #8583 **$44.95 ea.** (2.98)

.965" Kellner 18mm #8584, 25mm #8585
.965" Achromatic Huygenian 40mm #8586
$34.95 ea. (2.98)

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The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated.
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Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Guaranteed to beat other brands selling for much more! Unsurpassed high-performance design!

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12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into power panel drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.
#8482 ~~$69.95~~ **SALE! $59.95** (3.45)

9mm Illuminated Reticle

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.
#8488 ~~$119~~ **SALE! $109** (3.67)

Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

This new 12.5mm 4-element Plössl offers unprecedented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustable brightness. Features double crossline reticle.
#8484 ~~$99~~ **SALE! $89** (3.45)

6mm Illuminated Reticle

6mm Orthoscopic design for high power guiding, unique X-Y adjustable reticle positioning for easy guide star alignment. Wireless LED illuminator has adjustable brightness.
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Orion Plössl Eyepieces

Orion Multi-Coated Plössl eyepieces are fine performers at an amazingly low price. Precision 4-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!
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Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye relief.

10.5mm—An incredible 67° field for outstanding planetary or deep space performance.
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Guaranteed high-performance, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

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Orthoscopic Eyepieces*—Excellent Performance*
5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526
$49.95 ea. (2.98)

Ultrascopic 3-Element Barlow

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.
#8750 **$59.95** (3.45)

VariPower™ 2-3x Barlow

Fills the gaps in your eyepiece collection. Internal lens cell slides easily to adjust magnification. Quality optics provide excellent sharpness, contrast and brightness. Works with 1.25" diameter eyepieces and right-angle diagonals.
#8748 **$52.95** (3.45)

Fully-Baffled Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.
#8746 **$44.95** (2.98)

Filters

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective coated. Piggyback precision aluminum cells. Solar system observations are dramatically improved by Orion colored filters. Thread one into the barrel of any standard eyepiece. Can also be threaded directly into a universal camera adapter.

.965" Basic Set of 4 Filters Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5510 **$34.95 set** (2.98)

1.25" Basic Set of 4 Filters
Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5514 **$39.95 set** (2.98)

1.25" Expansion Set of 4 Filters
Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue. #5516

1.25" Advanced Set of 4 Filters
Includes #8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green. #5570

SALE! $29.95 set (2.98)

More Color Eyepiece Filters

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.
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Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.
#5575 **$109** (3.67)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544), #8 Yellow (#5571), #23A Light Red (#5572), #38A Deep Blue (#5573), #56 Light Green (#5574)
$11.95 ea. (2.43)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$13.95** (2.43)
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SkyGlow™ Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

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Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
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52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.
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SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces.
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Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
#5656 ~~$119~~ **SALE! $109** (3.67)

NEW! 2.0" Broadband Filter–
#5659 **$89.95** (3.45)

NEW! .965" Broadband Filter–
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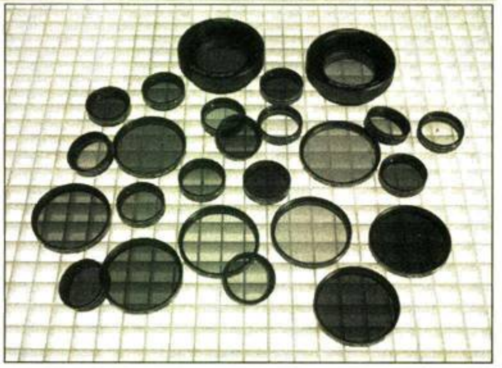

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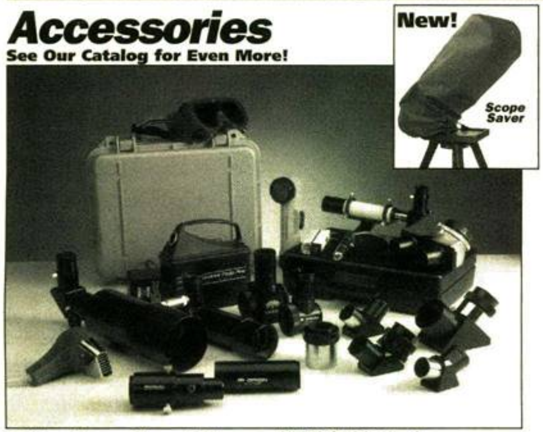

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For refractors: #8773
For Schmidt-Cass.: #8772 **$99.95** (3.45)

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1.25" Focuser #13007 **$49.95** (2.98)
2" & 1.25" Focuser #13003 **$84.95** (3.95)

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Advanced features at a low price. Use with Meade or Celestron SC. Easily adjustable prism. Ultra-precise helical focus of your eyepiece, adjustable camera focal plane position.
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Orion® Premium Off-Axis Guider

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Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately).

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Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

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AC Model #3504 **$44.95** (2.98)

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AC Model #3508 **$49.95** (2.98)

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Regular Case: 16"x12"x6.5"
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Large Case: 19.5"x12"x6.5"
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Scope Saver Telescope Covers

Keep your Schmidt-Cassegrain covered and keep the dust and dew away! Fits the telescope either on the tripod or in the case. Blue waterproof nylon fabric. Drawstring closure with cord lock.

8" Model #15130 **$33.95** (2.43)

10"-11" Model Fits Meade 10" and Celestron 11"
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Ask about other sizes.

Deluxe Eyepiece Case

This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug fit. O.D. 8-1/2"x12-1/2"x3-1/8".
#5913 **$17.95** (2.78)

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Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model—Has adjustable height center column and padded vinyl seat. Folds for easy storage.
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clamor of a sunstruck afternoon. And with the softening of visual cues, I seem to hear more clearly. The night, particularly in summer, scintillates with the grand noise of life responding to the regime of darkness. Most of these impressions are ruined by gluts of artificial light. As Paul Simon wrote later in the song, "And the people bowed and prayed / to the neon god they made."

I'll grant that a yard light is handy occasionally, but I can't understand why people don't use them as needed. Once you negotiate the icy walk between car and backdoor, just shut the thing off. The owls don't need it and your neighbors don't really want it either. Why move into the bush — where one of the chief reasons to be there at all is an awesome star-studded night sky — and then blot out the natural nocturnal peace with an energy-sucking floodlight?

We make much of water pollution by organic and inorganic chemicals, and rightly so. But light can pollute a lake just as readily. Fifteen years ago I could sit on the shore of Little Sturgeon Lake and spot two or three security lights along the far shore. The night wasn't pristine, but it wasn't shattered either. Now, especially in summer, security lights girdle the shore and the water is sliced with dozens of reflections. When people dump that much careless light onto the lake, can sewage be far behind? The mindset that pollutes is the same.

I once saw a satellite's-eye-view of North America at night and was shocked. Even from 20,000 miles out, the continent is splotched with seas of light. The night has deteriorated to the point where some observatories have been effectively hobbled by artificial daylight — glaring, starscape-killing grids of millions of bulbs. I'll concede that it's desirable to light city thoroughfares that never cease to hum with traffic. But our current levels of lighting are as much a product of "cheap" energy as the need to see clearly at night. We can afford to do it, so why not?

I can only say to the light junkies: use light only when you need it. Unfortunately, in many places you won't save money (that archaic, sinful flat rate), but you will save energy. This makes you more environmentally responsible.

My second message to the light junkies is: check out the beauty and the benefit — to you personally — of moonlight, starlight, and the northern lights. Once your eyes adjust, you won't need a mercury vapor fix. And the boogeyman won't spot your pit bull until it's too late. □

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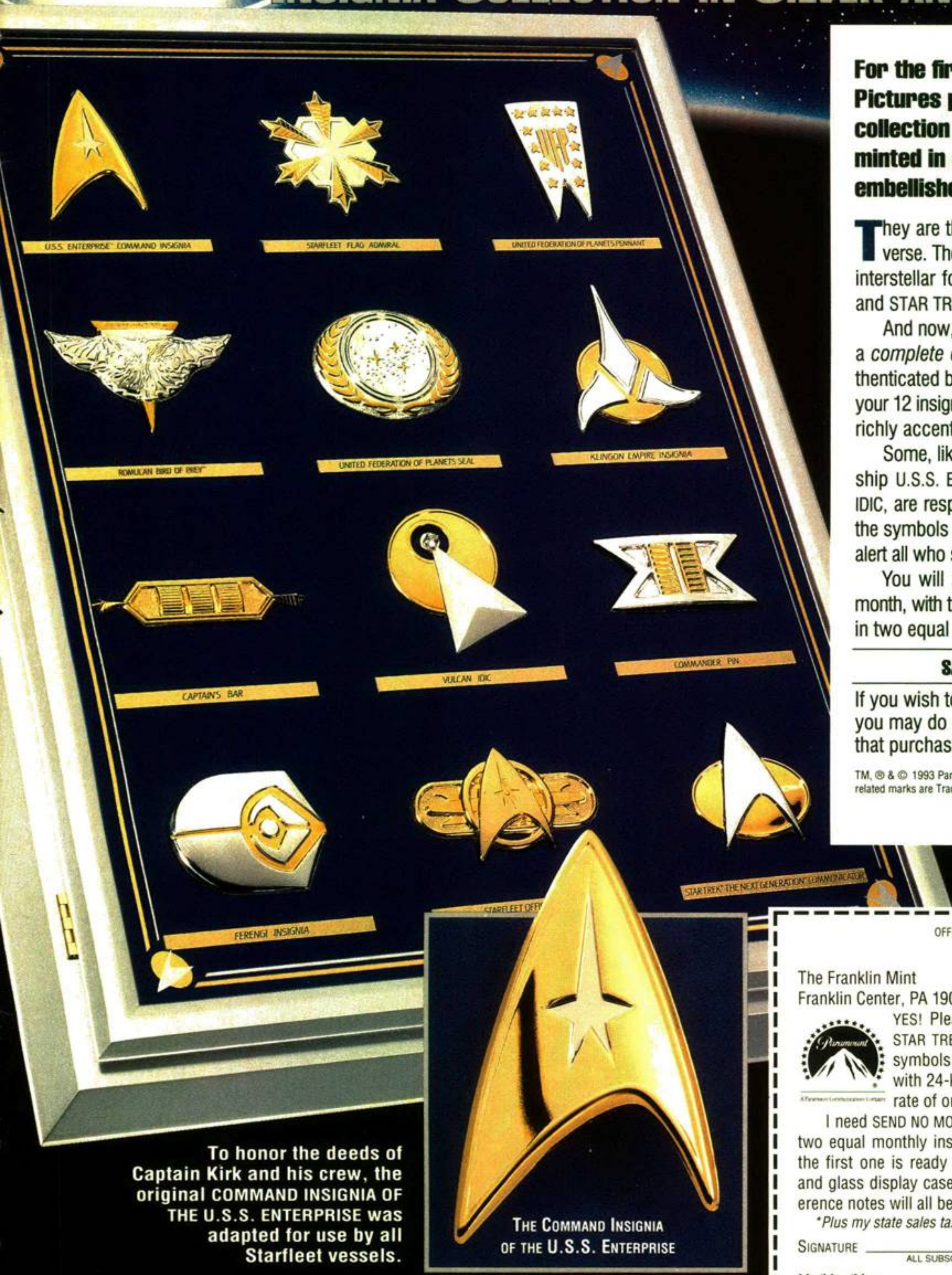
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HUBBLE DISCOVERS PROTOPLANETARY DISKS IN ORION NEBULA

Astronomers studying a small part of the Orion Nebula with the Hubble Space Telescope have found 15 young stars surrounded by extended disks of dust, just the kind expected of stars that are forming planetary systems. Though astronomers have long thought that planets should be common in our Galaxy, they have never seen any beyond our solar system.

If current theories are correct, planets arise in the dusty disks surrounding stars forming out of clouds of interstellar gas and dust. Particles of dust in these so-called protoplanetary disks collide, stick together, and grow larger, eventually reaching planetary size.

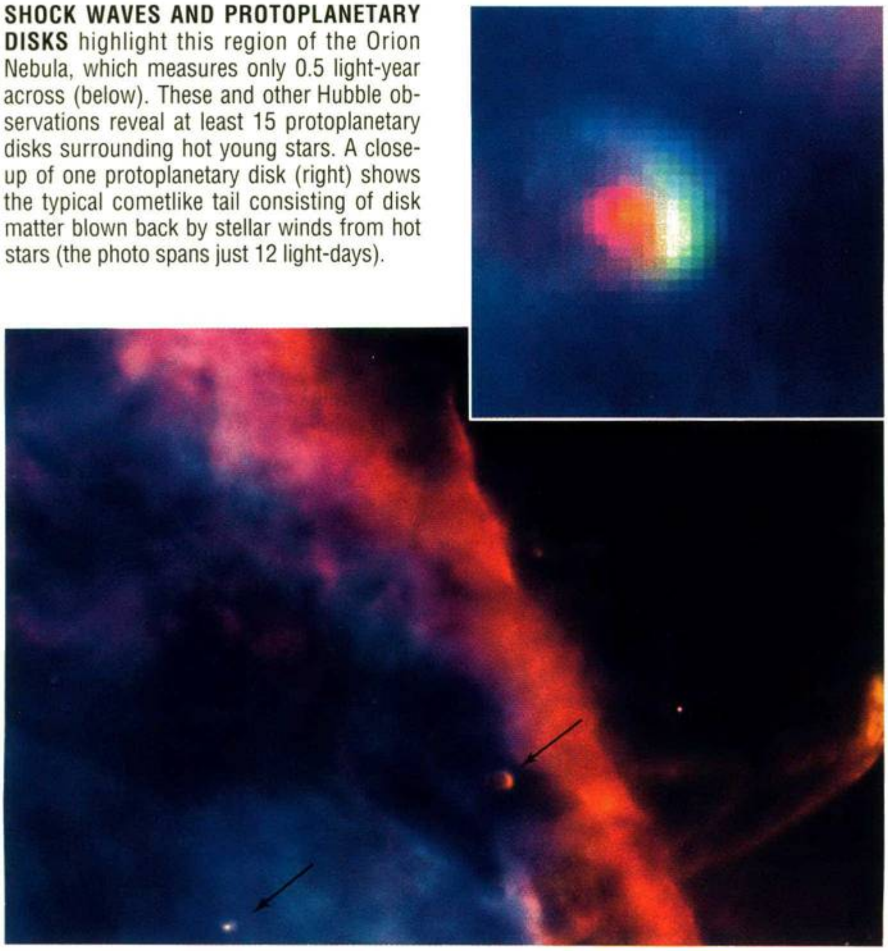
Before the Hubble discovery, dusty disks had been found around only four stars: Beta Pictoris (see following story), Alpha Lyrae (Vega), Alpha Piscis Austrini (Fomalhaut), and Epsilon Eridani. But these stars are significantly older than those in the Orion Nebula. The disks found by Hubble represent an entirely new class of object. They all belong to stars less than a million years old that appear to still be contracting — the perfect environment for forming planets.

"The disks are a missing link in our understanding of how planets like those in our solar system form," says C. Robert O'Dell of Rice University, the leader of the team that made the discovery. "This establishes that the basic material of planets exists around a large fraction of stars. It is likely that many of these stars will have planetary systems."

Each protoplanetary disk appears as a thick disk with a hole in the middle where the star lies. Radiation from nearby hot stars boils off material from the outer edge of the disk at a rate of about one-half the Earth's mass each year. Stellar winds of radiation and subatomic particles streaming from the hot stars then blow this material into a tail. Based on the erosion rate, O'Dell estimates that these protoplanetary disks initially contain at least 15 times the mass of Jupiter.

The observations suggest that nearly half the 50 stars in this part of the Orion Nebula have protoplanetary disks. If other stellar nurseries contain a similar fraction, then our Galaxy may be swarming with planets.

SHOCK WAVES AND PROTOPLANETARY DISKS highlight this region of the Orion Nebula, which measures only 0.5 light-year across (below). These and other Hubble observations reveal at least 15 protoplanetary disks surrounding hot young stars. A close-up of one protoplanetary disk (right) shows the typical cometlike tail consisting of disk matter blown back by stellar winds from hot stars (the photo spans just 12 light-days).



C. R. O'Dell and NASA

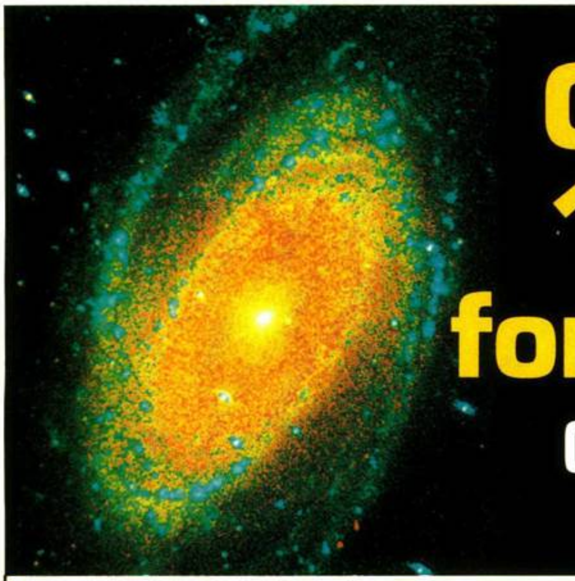
A CLOSER LOOK AT BETA PICTORIS

Beta Pictoris has a dust disk surrounding it but astronomers don't know if a planet has formed in this disk. If one has, it should clear the central region of the disk of dusty material. A new study shows that dust exists in as close as 30 astronomical units (1 AU is the average distance between the Sun and Earth).

As reported in the October 1992 AstroNews, previous studies could probe to within only 45 AU, or about 3 arcseconds as seen from Earth. This is so close that the star's light had to be blocked by a small occulting disk in the camera to view the dust disk. However, Alfred Vidal-Madjar of the Institut d'Astrophysique in Paris and his coworkers used a special CCD camera to probe within 30 AU of Beta Pictoris. The CCD had an antiblooming feature that prevented the light from the star from spreading into neighboring pixels and hiding the dust disk.

Their results confirm those from earlier studies showing that the particles in the outer disk are rather large, bigger than 0.001 millimeter in diameter. They also found that the particles reflect four times less light at 30 AU than at 75 AU. A change in particle size alone cannot explain the result; instead the nature of the grains must change with distance from the star. A possible explanation is that the icy particles closer to the star contain more dust.

Improvements in the new technique might permit a glimpse of Beta Pictoris' dust disk as close as 1 arcsecond from the star, which corresponds to a distance of 15 AU. Observations at this distance may help astronomers learn whether a planet has cleared the dust disk near to the star.



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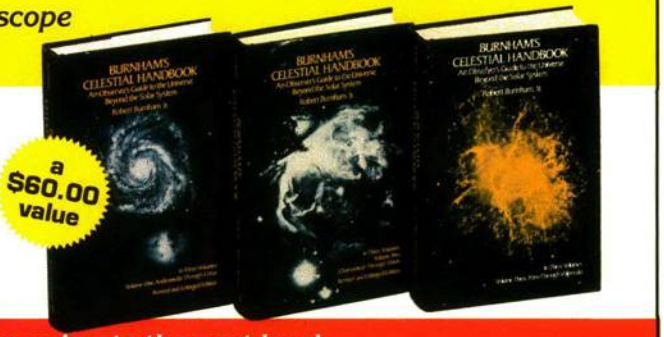
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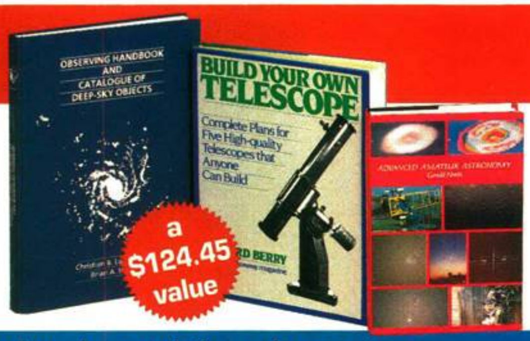
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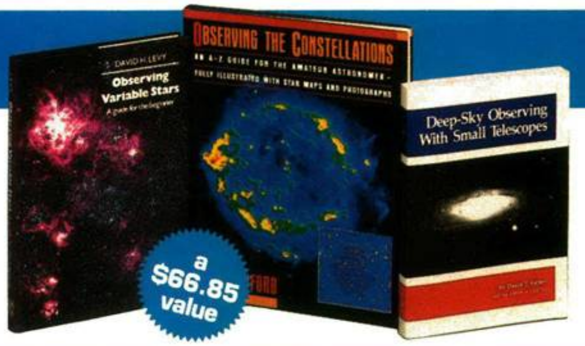
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CRISIS AT PROCYON?

Procyon is one of the 10 brightest stars in the sky, so you'd think it was well understood. Yet a recent measurement of Procyon's mass suggests that all is not well with models of the star's interior.

Alan Irwin of the University of Victoria in Canada and his collaborators made precise measurements of the orbit of Procyon and its white dwarf companion. From these measurements, they determined that Procyon is 1.75 times as massive as the Sun and its companion is about 0.6 times as massive. But Procyon appears two times less luminous than it should for its mass.

As the astronomers report in the July 1992 *Publications of the Astronomical Society of the Pacific,* either models of the star's interior are wrong for this star or the visual measurements of its orbit are incorrect. A small change in the separation of the stars — 0.2 arcsecond — would drop Procyon's mass to 1.5 times the Sun's and resolve the discrepancy between mass and luminosity. Because the visual measurements are several decades old, new observations of the orbit may help to solve the discrepancy between Procyon's luminosity and its mass.

COMET SWIFT-TUTTLE THREAT FADES

Relax. Doomsday has been canceled. It appears that Comet Swift-Tuttle won't smash into Earth after all when it returns in 2126. Concern over such an impact arose last October, shortly after astronomers recovered the parent comet of the Perseid meteor shower.

Based on early observations of the

Space News

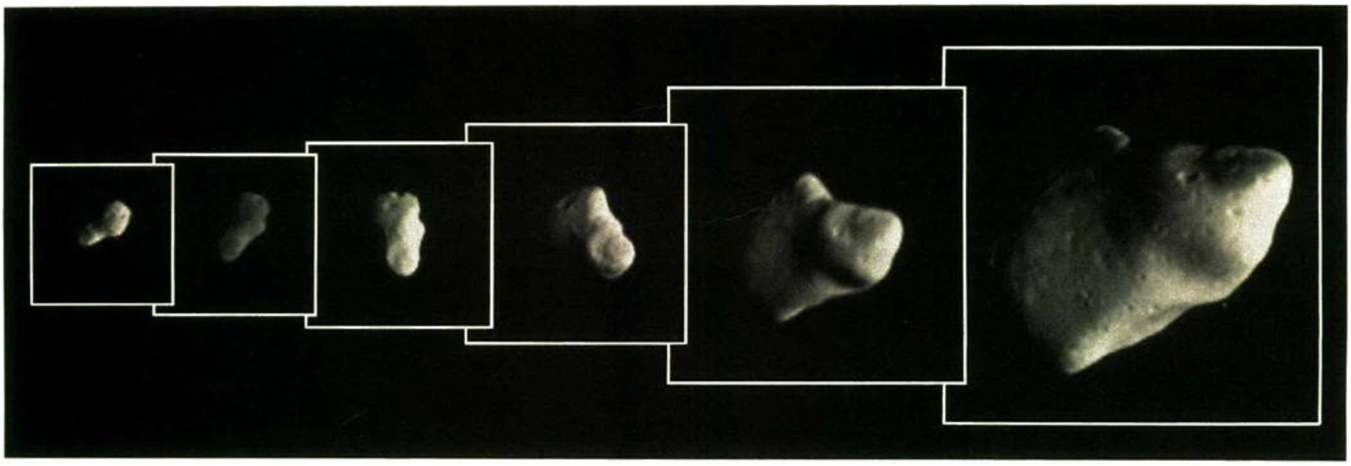
ASTEROID GASPRA SURPRISES ASTRONOMERS

Galileo's images of Gaspra taken in 1991 quickly became the classic textbook examples of what an asteroid looks like. But this "typical" asteroid has taken on a unique character. This past December, Galileo mission scientists announced that this 16-kilometer-long chunk of rock appears to have a magnetic field. It was a surprising discovery. Small asteroids aren't supposed to have magnetic fields — such fields are generated by the churning of molten iron cores, and only large worlds such as planets are candidates for molten cores.

The announcement was part of a package of new information about Gaspra released in late 1992. Although Galileo flew past Gaspra on October 29, 1991, the only data scientists had seen since then were a handful of images. The rest of Galileo's Gaspra discoveries had remained on board the spacecraft, stored on a tape recorder awaiting playback when Galileo neared Earth in late 1992 during the second of its Earth gravity-assist maneuvers. (See "Galileo Returns to the Earth and Moon," March 1993.) So while Gaspra's image has become a familiar sight in magazines and books during the last year, it is only now that scientists have the complete record of Galileo's 1991 encounter.

The biggest surprise in the new data is the detection of this apparent magnetic field around Gaspra. Just before closest approach to Gaspra, Galileo's "compass needle" swung dramatically to aim at Gaspra and then three minutes later it swung back to its normal direction. "Normal" means the direction of the interplanetary magnetic field created by the wind of particles blowing out from the Sun. The most likely explanation is that Galileo flew through a cavity punched in the solar wind by a magnetic Gaspra. Explains Margaret Kivelson, head of Galileo's magnetometer experiment, "The two magnetometer excursions represent Galileo's passage across two wakes in the magnetic field — like a ship crossing the bow wave and stern wave of another craft."

GASPRA SPUN END FOR END as Galileo approached the rocky world. In the first image (left) the "snout" of Gaspra is aimed away from the camera, but it gradually rotates into view, ending up aimed at the camera in the now-familiar close view (right).



NASA

comet's position, Brian Marsden of the Harvard-Smithsonian Center for Astrophysics calculated that Swift-Tuttle would next return to perihelion on July 11, 2126, with a margin of error around 20 days. If the comet reached perihelion just 15 days later, it could collide with Earth on August 14, 2126 (see "Return of the 'Perseid Comet,'" January 1993). Though the chances were slim — a mere 1-in-10,000 possibility — many in the media focused on what could be a potentially catastrophic impact.

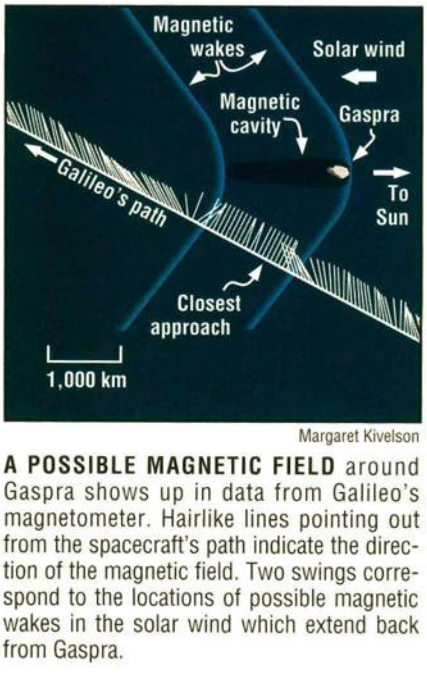
By early December, however, enough observations had accumulated to rule out this scenario. Orbital calculations and historical records showed that Swift-Tuttle had been seen from Earth several times before — not only in 1737 and 1862 as already known, but very likely in 68 B.C. and A.D. 188. Combining all these observations gave a more precise orbit that narrowed the predicted date of the next perihelion to within a day of July 11, 2126. That rules out a collision in 2126 and, according to Marsden, makes the prospect of the comet's colliding with Earth in the next millennium very unlikely.

At the surface of Gaspra, the strength of the field would be about one-tenth to 10 times the strength of the field at the surface of Earth — the uncertainty comes from the fact that Galileo did not actually measure Gaspra's magnetic field, only its effect on the solar wind.

The origin of Gaspra's field is a mystery. Gaspra is certainly too small to have a molten core itself. But it does imply that Gaspra has a great deal of iron in its composition. Gaspra's irregular shape — it measures 16 by 14 by 12 kilometers — suggests that it is a fragment of something bigger. Perhaps Gaspra was once part of the iron-rich core or mantle of a larger object. Despite whatever catastrophic event shattered its parent world, Gaspra managed to retain traces of the parent's magnetic field.

The creation of Gaspra as a separate object may have occurred relatively recently. Although the figure is a matter of debate, the best estimate is that the surface we see on Gaspra now is no more than 200 million years old. Back then something reshaped the surface — either the event that broke Gaspra off its parent asteroid or a massive impact that erased all traces of the older surface.

Evidence that Gaspra experienced the latter comes from grooves running across its cratered surface. To asteroid experts, the grooves suggest one thing: a massive impact big enough to fracture the asteroid. According to Michael Belton of the National Optical Astronomy Observatories, "Gaspra's gravity holds its shape together but deep inside it's broken up." In fact, Gaspra may not even be a single object. It has what looks like a snout on it. Points out Belton, "This could be a small piece welded onto the larger body of the asteroid. The fractures we see may be evidence for this."



Margaret Kivelson

A POSSIBLE MAGNETIC FIELD around Gaspra shows up in data from Galileo's magnetometer. Hairlike lines pointing out from the spacecraft's path indicate the direction of the magnetic field. Two swings correspond to the locations of possible magnetic wakes in the solar wind which extend back from Gaspra.

With its fractures, snout, and magnetic field, Gaspra is proving to be a remarkably complex object for one so small. Is it typical of asteroids? Later this year we'll get a look at another asteroid thanks to Galileo's scenic route to Jupiter. On August 28, 1993, Galileo will fly to within 1,600 kilometers of 243 Ida, an asteroid twice as large as Gaspra. Galileo scientists expect to get images of Ida with twice as much detail as those of Gaspra, including a series following Ida for an entire rotation at high resolution.

PROBING THE LOCAL GROUP OF GALAXIES

A key relation astronomers use to explore the evolution of structure and the distribution of matter in the universe is that between the number of galaxies and their brightnesses, the so-called luminosity function. However, it's difficult to study the luminosity function of distant galaxies because most small, faint galaxies remain largely unseen at large distances. To better explore what the luminosity function should look like, Sidney van den Bergh of the Dominion Astrophysical Observatory in British Columbia determined the function for our Local Group of galaxies.

Twenty-seven galaxies belong to the group, including the Andromeda Galaxy and the Large and Small Magellanic Clouds. These galaxies range in absolute magnitude from –21.1 to –7.6, a range of over 250,000 in luminosity. Van den Bergh reported in the October (I) 1992 issue of *Astronomy and Astrophysics* that no evidence exists for a lower limit to galaxy brightness: the number of galaxies continues to increase as astronomers look at fainter group members.

Van den Bergh also found that the ratio of low-mass (dwarf) galaxies to large, bright galaxies in our Local Group is less than the ratio in clusters rich with galaxies. The observed numbers of dwarf galaxies in galaxy groups and clusters may help astronomers understand whether these galaxies formed on their own as part of a hierarchy of galaxy types and sizes or whether they are the remnants of galactic collisions.

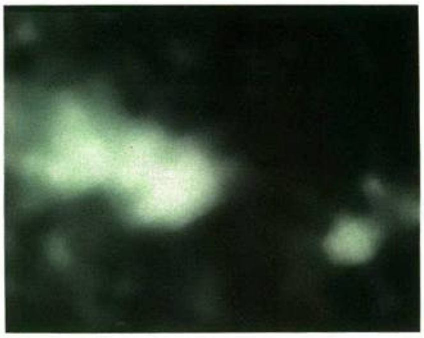
HUBBLE PROBES MOST DISTANT GALAXY

An unexpected chain of luminous knots highlights the Hubble Space Telescope's first look into the core of the most distant known galaxy. The galaxy, called 4C41.17, lies roughly 12 billion light-years from Earth, so we are seeing it as it was when the universe was only about 10 percent its present age.

Using the Wide Field/Planetary Camera on HST, a group of astronomers imaged 4C41.17 in unprecedented detail. "A surprising result is the extreme clumpiness of the visible emission, suggesting that the inner region of this primeval galaxy is highly disturbed," says George Miley of Leiden University in the Netherlands. Miley, along with coinvestigators Kenneth Chambers of the University of Hawaii, Wil van Breugel of Lawrence Livermore National Laboratories and the University of California, and Duccio Macchetto of the Space Telescope Science Institute and the European Space Agency, reported their findings in the December 20, 1992 issue of *Astrophysical Journal Letters*.

4C41.17 is also a well-studied radio galaxy, which has twin jets of high-speed particles emanating from its nucleus. According to Miley, the Hubble images turn out to look remarkably similar to radio images produced previously by the Very Large Array radio telescope near Socorro, New Mexico.

What causes the alignment between the optical and radio emission? One possibility is that the high-velocity jets of particles producing the radio emission also compress gas and dust along their paths, triggering new star formation. If true, the luminous knots seen in the image represent giant star clusters, each containing roughly 10 billion stars and measuring 1,500 light-years across. An alternative hypothesis holds that the optical emission is simply light scattering off clouds of gas or dust. In this view, the light presumably comes from an accretion disk surrounding a massive black hole in the galaxy's center. Clues as to which is the correct explanation will have to wait until after the Hubble servicing mission set for later this year. Only then will astronomers be able to study 4C41.17 and other similar objects in enough detail.


George Miley, Kenneth Chambers,

TO HST'S SHARP EYE the most distant known galaxy displays a clumpy internal structure, possibly revealing new star clusters that each contain 10 billion stars. Known as 4C41.17, this galaxy shines across a distance of roughly 12 billion light-years.

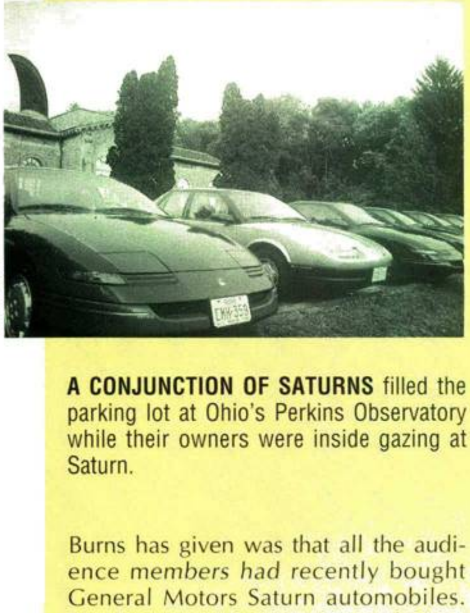
Amateur News

OWNERS OF SATURNS, MEET SATURN

"My God, the parking lot is full of Saturns." That was the reaction of Perkins Observatory Assistant Director Tom Burns upon walking out of the observatory after delivering an astronomy program to about 100 people. What made this program different from dozens of other astronomy programs Burns has given was that all the audience members had recently bought General Motors Saturn automobiles. The Saturn owners were at Perkins to see — what else? — Saturn through the observatory's 32-inch Cassegrain telescope. The program was the brain child of Columbus Astronomical Society (CAS) members and Tom Carpenter, president of the North Car Saturn dealership in Columbus, Ohio.

In 1991, CAS member Earl Phillips contacted the soon-to-be-built Saturn dealership, which was to be located just a few miles south of the observatory. He wanted to encourage the use of fully shielded lighting. North Car Saturn took up the idea and Carpenter later contacted Phillips with the idea of offering new Saturn owners the chance of going to a program at Perkins. In return, North Car Saturn made a series of donations to the observatory.

By the end of the summer in 1992, the dealership had sold more than 2,000 Saturns. More than 400 of those new Saturn owners took up the offer to see their car's namesake and received tickets to attend one of four special programs. So what is the future of Saturn programs? Burns is hopeful that North Car Saturn will continue the programs. The donations were especially welcome because the observatory's budget is tight. Still, Burns wonders if Saturn owners will be as happy to see Jupiter this spring as they were to view Saturn last summer. — *Robert Bunge*


Willke Cirker

A CONJUNCTION OF SATURNS filled the parking lot at Ohio's Perkins Observatory while their owners were inside gazing at Saturn.

BUILDING MOLECULES IN PLANETARY ATMOSPHERES

To better understand how complex molecules form in planetary atmospheres, Purdue University researchers are studying a key molecule, diacetylene. Diacetylene (C_4H_2) is one of the most important molecules in the solar system because it's extremely reactive when subjected to ultraviolet light, producing new molecules at a fast rate. Like ozone, it acts as an ultraviolet shield for the lower atmospheres and surfaces of planets such as Uranus, Neptune, and Pluto. Diacetylene is also present in the atmosphere of Titan, Saturn's largest satellite. Its high reactivity makes the molecule important for understanding the evolution of planetary atmospheres despite its low abundance in the solar system, less than one molecule per 10 million in Titan's atmosphere.

The researchers, led by Timothy Zwier, exposed diacetylene to ultraviolet light in a laboratory. The scientists found such products as C_8H_2, a molecule postulated by a planetary model, and two unanticipated molecules, C_6H_2 and C_8H_3. These latter molecules are large, linear molecules that themselves reacted to form yet other molecules. The next step in studying diacetylene's role in planetary atmospheres is to see how it reacts with other molecules present in the atmospheres of the outer planets.

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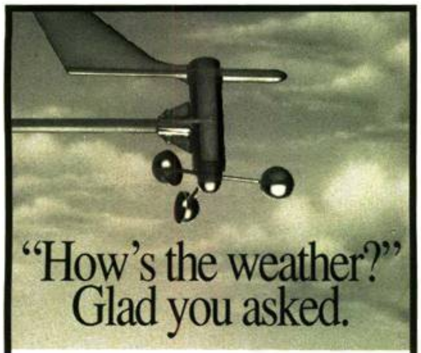

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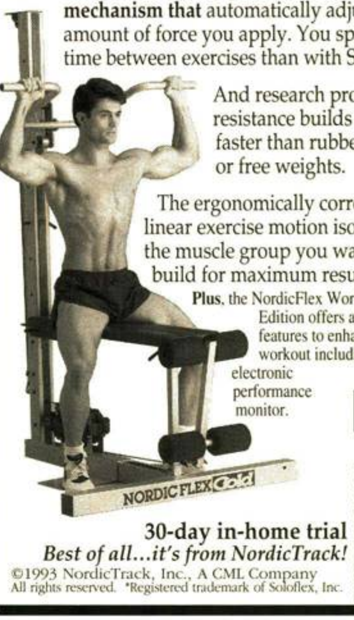

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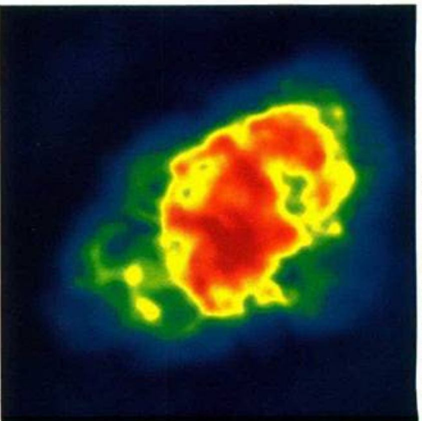
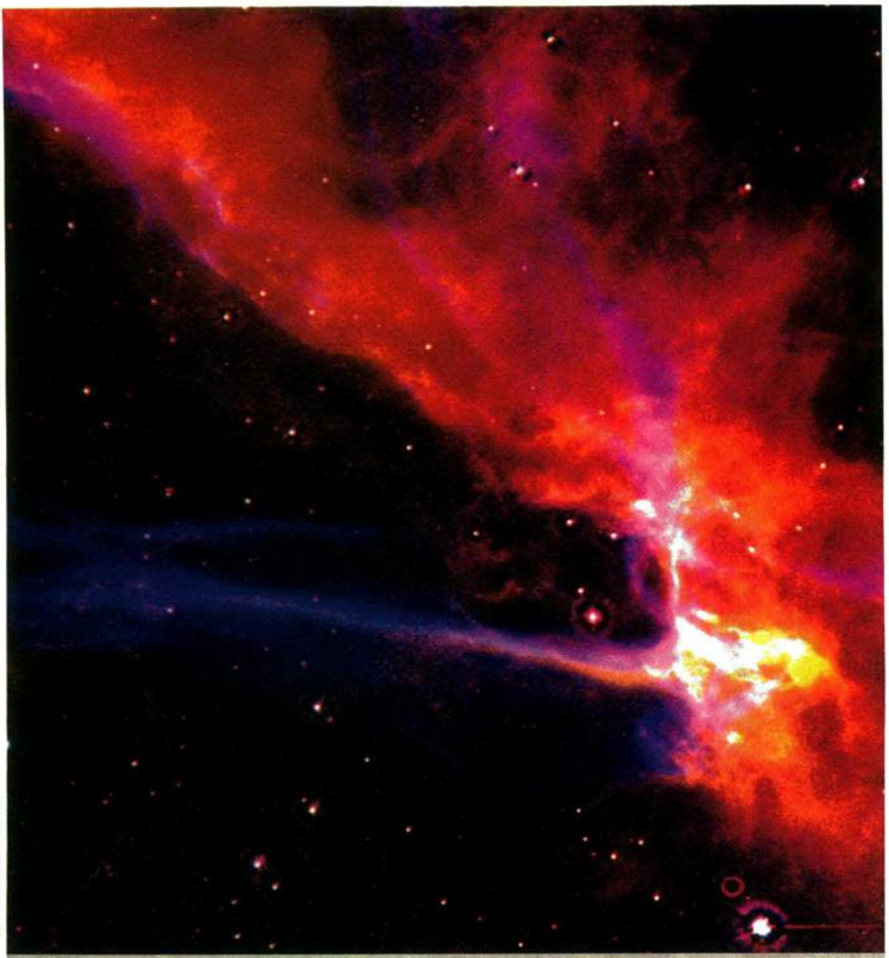
FIRST TELESCOPES NEAR COMPLETION ON MT. GRAHAM

Workers have installed the instruments and finished the exteriors of the buildings for the Sub-Millimeter Telescope and the Vatican Advanced Technology Telescope on top of Mount Graham near Safford, Arizona. Some interior work remains, but astronomers expect to start using the scopes this spring. The University of Arizona joined with Germany's Max Planck Institut für Radioastronomie to build the Sub-Millimeter Telescope and with the Vatican Observatory to build the Advanced Technology Telescope.

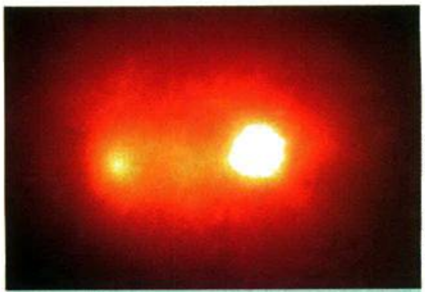
A fall census of the red squirrel population by the the U.S. Forest Service and Arizona Game and Fish Department estimated 290 to 394 squirrels live in the Pinaleno mountain range, which includes the observatory site. (The squirrel population had been the focus of environmental groups' efforts to stop observatory construction.) This is nearly double the count of 162 to 185 during the fall of 1989, when construction of the observatory began, and higher than the fall 1990 count of 250 to 300. It does mark a decrease from the fall 1991 estimate of 364 to 417, but a Forest Service biologist attributed this drop to a decline in the spruce, fir, and pine cone crop in the Pinalenos. The biologist also said that there was no discernible connection between the population fluctuations and observatory construction. ☐


T. J. Cornwell and J. M. Uson/NRAO

THE CRAB NEBULA glows in an image created by homogeneous mosaicking. This method expands the field of view of multiple radio telescopes by combining multiple bits of data with lower-resolution data to produce a combined image of exceedingly high resolution. In this image, which contains 40 percent more information than the previous best radio image, the radio emission from the Crab is color coded so red represents the highest energy emission, then yellow, then green, and finally blue. Researchers T. J. Cornwell and J. M. Uson used the Very Large Array radio telescope and part of the Very Long Baseline Array to create the image.


Jeff Hester and NASA

TENUOUS TENDRILS OF GAS in the Cygnus Loop light up as shock waves from a 15,000-year-old supernova plow through the interstellar medium. This Hubble Space Telescope image shows dense clumps of gas as small as our solar system just as they are overrun by the shock waves. The bluish ribbon of light stretching from left to right may be a knot of gas ejected by the supernova. Traveling at over 5 million kilometers per hour, this interstellar "bullet" is just catching up to the slower-moving shock front.


J. MacKenty and NASA

A DOUBLE NUCLEUS SPOTLIGHTS the core of the active galaxy Markarian 315 and hints at a titanic collision in the galaxy's past. The two nuclei seen in this Hubble Space Telescope image lie some 6,000 light-years apart. The brighter nucleus represents the energetic core of the galaxy, while the fainter nucleus appears to be the surviving core of a smaller galaxy that recently merged with Markarian 315. The galactic collision likely fueled a massive black hole located in the brighter nucleus, igniting the intense activity now seen. The collision also would help explain the nature of the galaxy's jet, which is 240,000 light-years long. It is apparently a tail of gas pulled out by tidal forces when the two galaxies collided.

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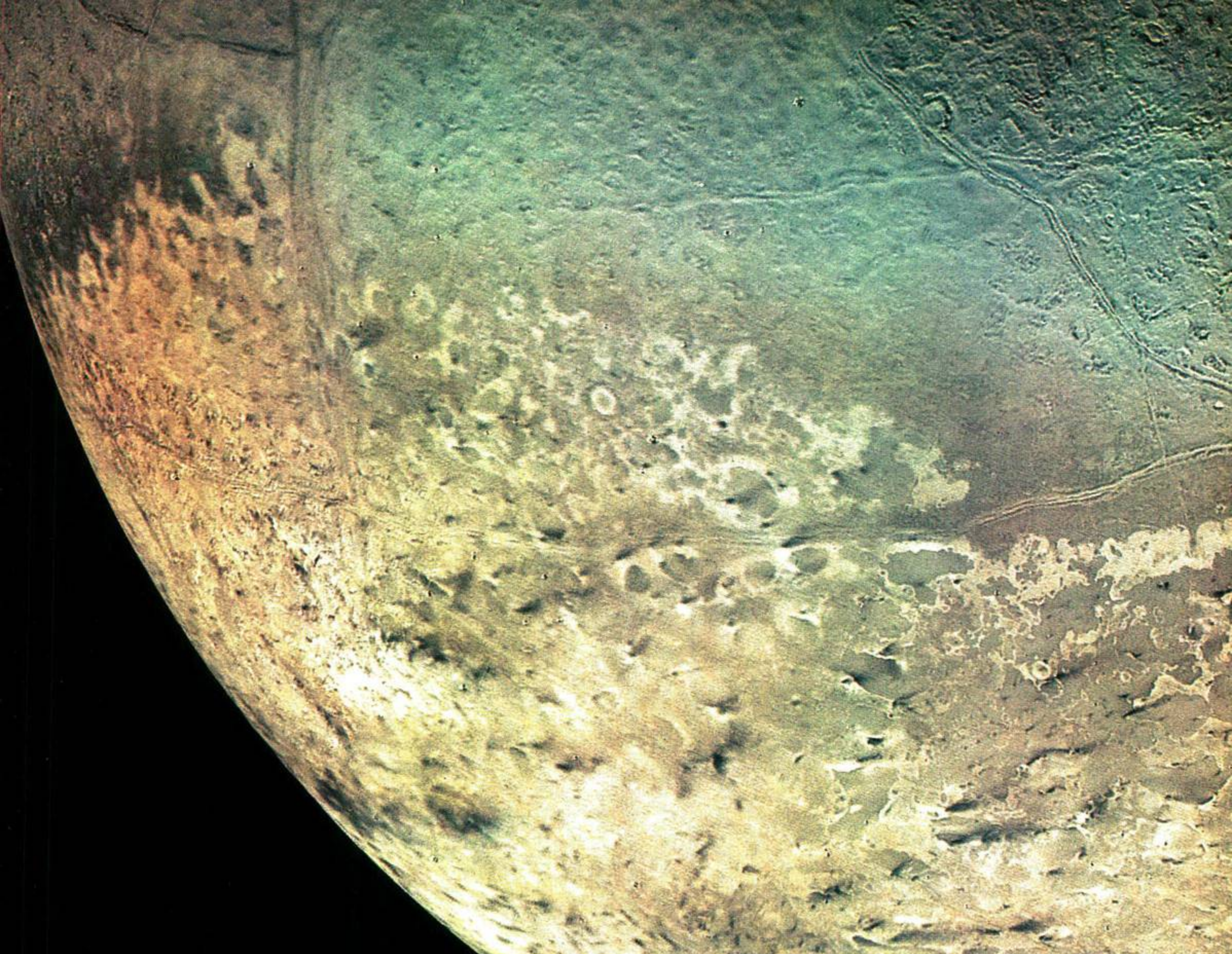
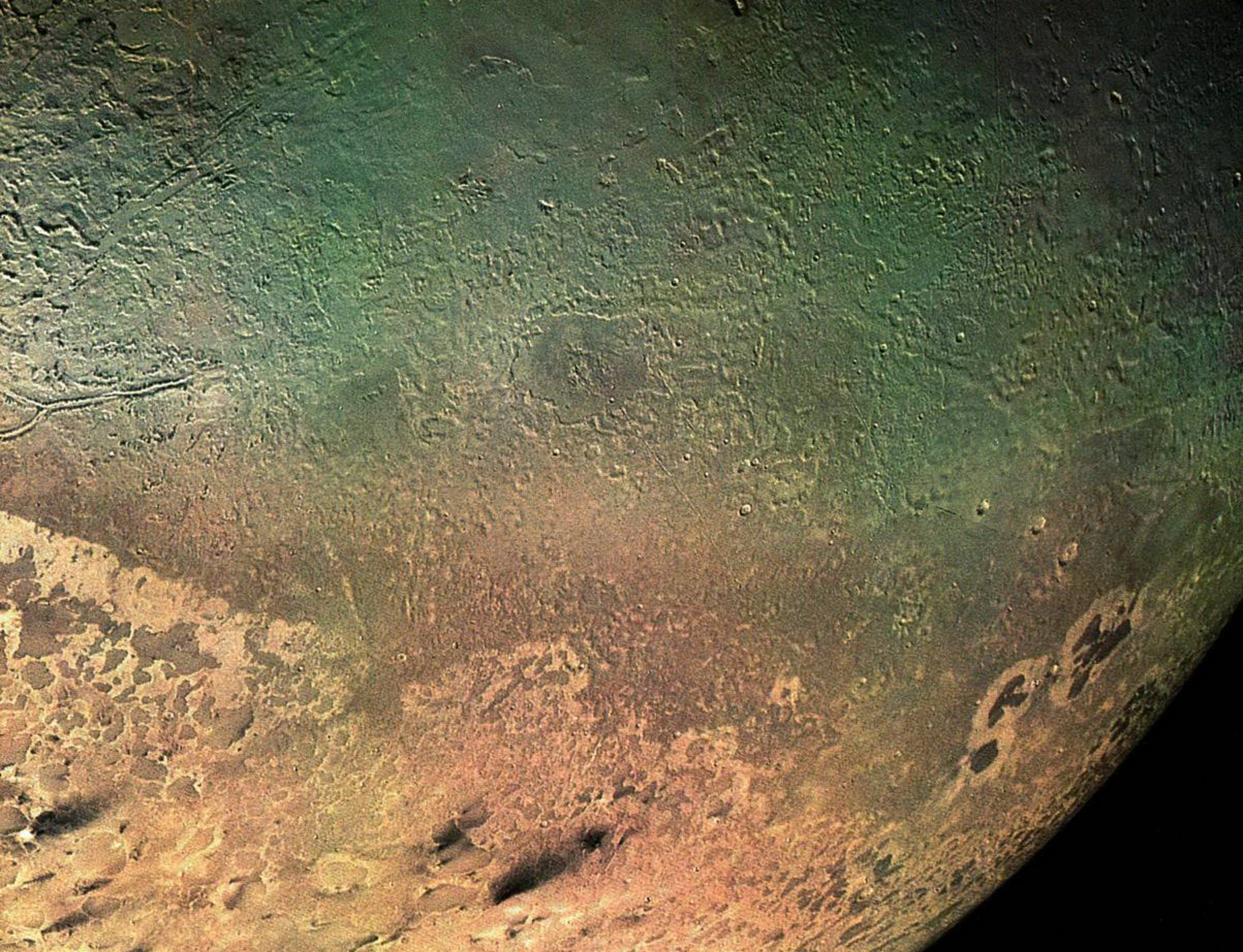


PLANETARY SCIENCE

THE TITAN/TRITON CONNECTION

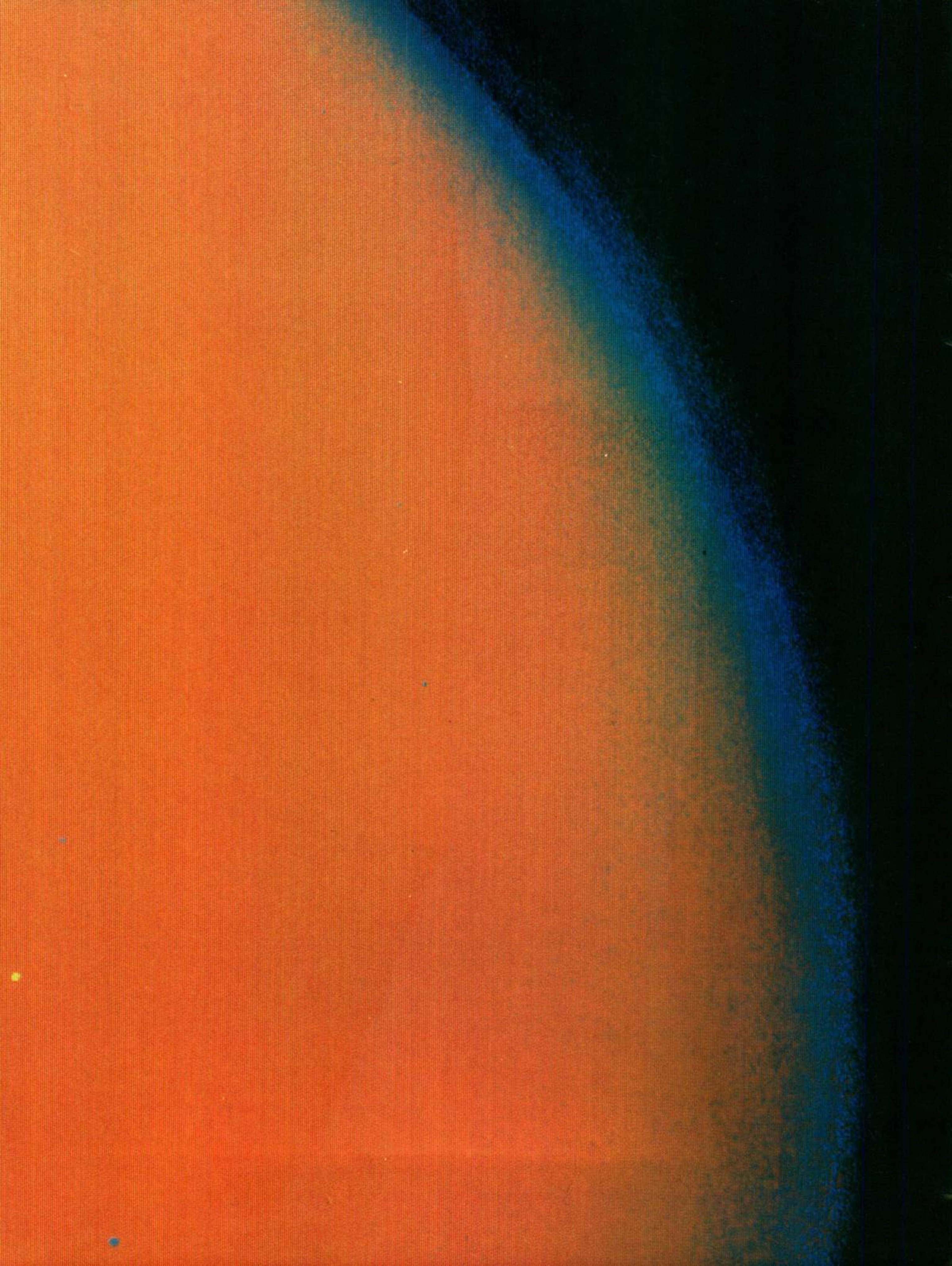
At a glance, Saturn's moon Titan and Neptune's moon Triton seem strikingly different. In reality their similarities offer clues about the history of the outer solar system.



MYSTERIOUS TRITON and its many-terrained surface were targeted by the Voyager spacecraft in 1989. Though locked in the deep freeze of the outer solar system, Neptune's standout moon holds many similarities to Saturn's moon Titan.

NASA/JPL

by KEN CROSWELL



CLOAKED BY CLOUDS, Saturn's Titan hid its surface from the Voyager spacecraft cameras. The moon's atmosphere (visible along the limb) contains nitrogen, ethane, and methane, and its surface probably has patches of water ice and thawed lakes and ponds.

NASA/JPL

The frontier of the solar system has long beckoned astronomers, not only because of the great diversity of worlds it encompasses but also because it holds some of the clues to the solar system's origin. In 1997 NASA will launch the Cassini mission to Saturn, which five years later will drop a probe into the atmosphere of Saturn's largest moon, Titan. And early next century, scientists hope to send an orbiting spacecraft to distant Neptune, in large part to explore that planet's biggest moon, Triton.

Why so much attention on Titan and Triton? At first glance they seem to be rather ordinary, if large, moons. But Saturn's Titan and Neptune's Triton preserve clues to the nature of the outer solar system. In the wake of the Voyager missions to the outer planets, scientists have learned that Titan and Triton have both important similarities and differences, and these are providing insight into the processes that occurred as the solar system was being born. They may also help reveal the nature of another distant world, one that astronomers have never seen close-up but would like to visit: mysterious Pluto.

Exploring Titan and Triton

Long before Voyager flew past them, Titan and Triton were special worlds to astronomers, for both moons are large, belonging to the "Big Seven." Of the 61 known moons in the solar system, only seven are large: Earth's Moon, Jupiter's four Galilean satellites, and Titan and Triton. Titan and Triton are the most distant of the seven big moons.

Because of the moons' great distances, astronomers had to struggle to learn what they could about Titan and Triton. Christiaan Huygens discovered Saturn's Titan in 1655. William Lassell discovered Neptune's Triton in 1846. But astronomers made little progress in understanding either satellite until well into the twentieth century.

Titan made a name for itself in 1944 when Gerard Kuiper discovered methane gas (CH_4) around it. Up to that time, only planets were known to have atmospheres. Although Titan is smaller than most planets, it is so cold that molecules in its atmosphere move slowly and Titan's weak gravity can hold onto them.

During the 1970s astronomers discovered clouds on Titan, further proof that it has an atmosphere. Scientists then detected more complicated hydrocarbons such as ethane (C_2H_6) in its atmosphere and suggested that Titan's orange color arises from complex organic compounds created when sunlight strikes methane.

But they missed the atmosphere's principal ingredient: nitrogen, the same gas that makes up 78 percent of Earth's atmosphere. Donald Hunten of the University of Arizona had predicted that nitrogen makes up most of Titan's atmosphere, but hardly anyone believed him. In 1980 the Voyager 1 spacecraft flew past Saturn and found Titan cloaked in orange haze so opaque no view emerged of what lay below. Rather than scrutinize the surface of Titan, Voyager could study only Titan's atmosphere.

Fortunately, the atmosphere turns out to be as interesting as anything it might be hiding. Voyager found a thick atmosphere with a surface pressure 1.5 times that of Earth's. Furthermore, as Hunten predicted, the main gas is not methane but nitrogen. Voyager also measured Titan's surface temperature as 94 kelvins (–290° F), warm enough that Titan may harbor lakes or even seas of methane and/or ethane.

Meanwhile, astronomers on Earth were making progress in their studies of Neptune's moon Triton, despite the satellite's much greater distance. They had already detected methane on Triton, suggesting that it has both methane ice on its surface and methane gas surrounding it. Triton, like Titan, has an atmosphere.

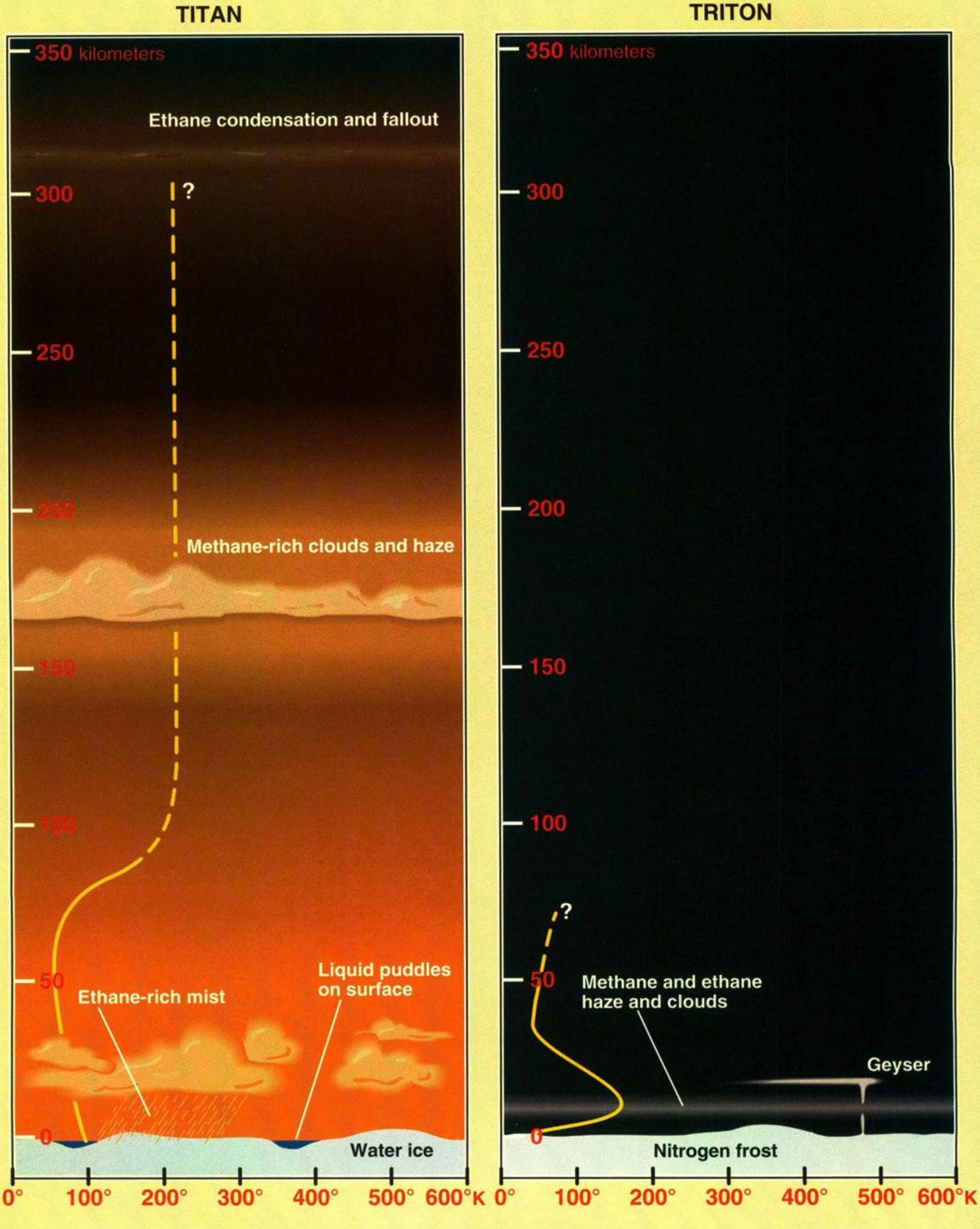
Then, in 1983, Dale Cruikshank (NASA Ames Research Center), Robert Brown (Jet Propulsion Laboratory), and Roger Clark (University of Hawaii) reported spectroscopic evidence for nitrogen on Triton. The nitrogen they detected was not gaseous, however. Instead, the spectra indicated that Triton's nitrogen is in liquid and solid form. This surface nitrogen also implies that Triton has at least a tenuous nitrogen atmosphere. Moreover, if Triton were warm enough, said Cruikshank and his colleagues, the satellite might harbor seas of liquid nitrogen.

When Voyager 2 flew past Neptune in 1989, the spacecraft measured Triton's mass, size, density, and temperature, finding Triton smaller and colder than scientists expected. Triton's temperature is only 38 K, far too cold for seas of liquid nitrogen.

Yet, as Cruikshank's team had predicted, nitrogen is the dominant component of Triton's atmosphere. The atmosphere is tenuous, with a surface pressure only $^{1}/_{65,000}$th that of Earth's, so Triton readily reveals its strange surface: pastel-colored nitrogen and methane ice with tall plumes eight kilometers high

Atmospheres of Titan and Triton

Titan and Triton's atmospheres differ substantially in terms of temperature and composition. The curves show temperature measured as a function of height.



that probably arise from geysers shooting nitrogen gas into the thin air.

A Round Trip from Titan to Triton

At first glance, Titan and Triton look like two completely different worlds — the first engulfed by a thick atmosphere, the other so cold it has little atmosphere at all. Yet Cruikshank sees similarities. "At the time before the Voyager encounter with Triton," he says, "we had begun to converge on a view of Triton as a frozen-out Titan, and in that sense the Voyager results largely confirmed this view. I think it's fair to say that with our present understanding of Titan and Triton, they're interchangeable. If you put one in the other's place, it would turn into the other body."

The most obvious similarity is the high abundance of nitrogen, a gas on Titan and an ice on Triton. Like nearly anything else, nitrogen can exist as a gas, a liquid, or a solid, depending on the temperature and pressure. At a pressure of one Earth atmosphere, nitrogen is a gas at temperatures above 77 K — which is why nitrogen on both Earth (300 K) and Titan (94 K) forms an atmosphere. Below 77 K, nitrogen is liquid, and below 63 K, it forms a solid. Therefore, most nitrogen on frigid Triton (38 K) is an ice.

Titan and Triton also contain methane and other hydrocarbons. When sunlight and cosmic rays strike methane, they convert it to more complex organic compounds that color the satellites. Both satellites owe their color to complex organic compounds. Titan is orange, and parts of Triton are pink and pale yellow.

Thus, says Cruikshank, Titan and Triton are basically similar worlds that owe their apparent differences mostly to their different temperatures — which are themselves simply a result of the two worlds' differing distances from the Sun. Titan is about a billion miles distant, whereas Triton is nearly three billion miles away.

Suppose we took Titan away from Saturn and moved it out to Neptune. What would happen? Says Cruikshank, "I think you would probably get something that looks very similar to Triton." Titan's temperature would drop, and the nitrogen gas that now makes up its atmosphere would condense into a liquid and then freeze into an ice. So would the methane.

Likewise, if we took Triton away from Neptune and moved it up to Saturn, the opposite would happen, with the temperature rising. "In principle, it would end up the way Titan is now," says Cruikshank. The nitrogen ice would melt and form seas of liquid nitrogen. As the temperature rose further, the liquid nitrogen would boil and create a thicker nitrogen atmosphere, perhaps like Titan's.

What if we put one of these worlds at an intermediate distance, into orbit around Uranus? Then the temperature should be intermediate, too, and might be just right for liquid nitrogen. Such a Uranian satellite might have seas of liquid nitrogen similar to the seas of liquid water that cover most of Earth. "That would be an interesting opportunity," says Cruikshank, "but nature didn't give us one." Uranus is the only giant planet that has no large moons.

But Differences, Too

Titan and Triton are hardly identical. Their compositions are similar but differ in proportion and chemistry. Titan consists of a rocky core 3,400 km in diameter surrounded by four distinct layers of ice with distinctly different densities and crystal structures. The density of ice inside the moon is much greater than that closer to the surface. Titan may harbor a liquid ocean of ethane, methane, and/or water, although a recent study by a group of planetary astronomers led by Duane O. Muhleman of the California Institute of Technology, which bounced radar off of Titan, apparently has ruled out a global ocean on Titan. The moon may contain "ponds or lakes of hydrocarbons," according to Muhleman. Some 10 km above Titan's surface a cool mist of mostly ethane gas may fog the atmosphere, and at an altitude of 150 to 200 km a cold layer of methane haze blankets the planet. Scientists suspect that much higher in Titan's atmosphere, some 300 to 320 km above the surface, relatively warm ethane forms and falls to the lower atmosphere in a cycle.

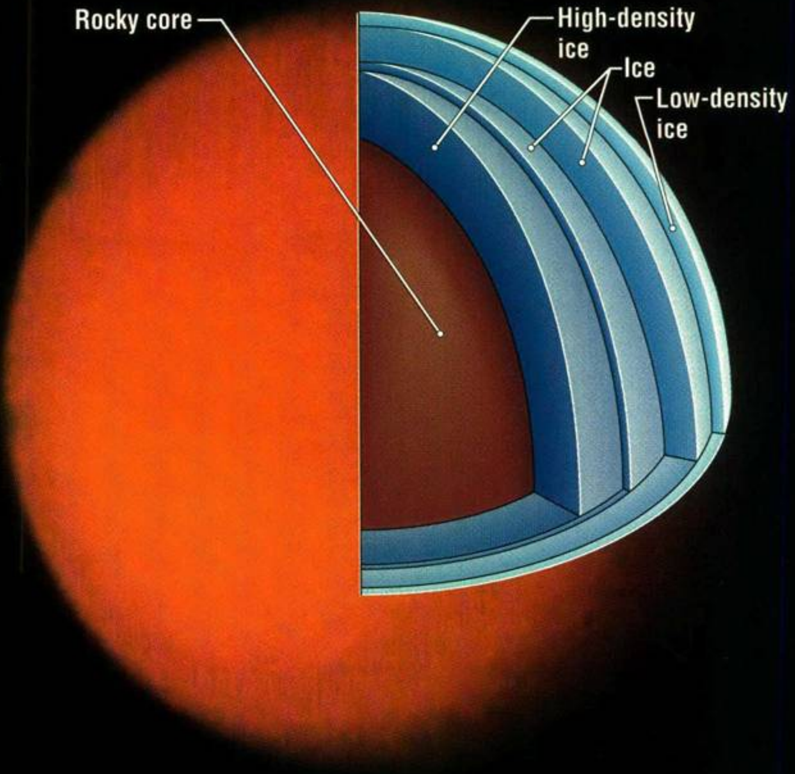
Neptune's Triton has a similar composition but differs from Titan in rock-to-ice ratio. Triton has a large rocky core, two thick layers of ice, and a nitrogen atmosphere. An ocean of liquid water may exist between the rocky core and the thick ice layers.

"But when you look at Titan," says William McKinnon of Washington University in St. Louis, "one of the first things you realize is that it has a lot less rock than Triton does. So that's a fundamental clue that these are not necessarily the same sorts of objects. Their rock-to-ice ratios are different, and we expect their ice-forming components to be different as well."

ASTRONOMY: Steven G. Davis

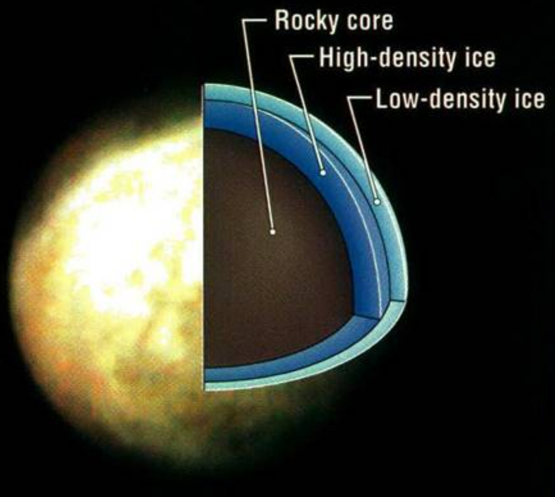
TITAN

Moon of: Saturn
Distance from Sun: 9.5 AU
Distance from planet: 1,221,850 km
Orbital period around planet: 15.945 days
Diameter: 5,150 km
Density: 1.88 g/cm^3
Surface temperature: 94 K
Main atmospheric gas: nitrogen
Surface pressure: 1.5 times Earth's
Discoverer: Christiaan Huygens (1655)


Rocky core
High-density ice
Ice
Low-density ice

TRITON

Moon of: Neptune
Distance from Sun: 30.1 AU
Distance from planet: 354,800 km
Orbital period around planet: 5.877 days
Diameter: 2,700 km
Density: 2.07 g/cm^3
Surface temperature: 38 K
Main atmospheric gas: nitrogen
Surface pressure: 0.000015 times Earth's
Discoverer: William Lassell (1846)


Rocky core
High-density ice
Low-density ice

Astronomers can deduce an object's composition from its density. The moons of the outer solar system consist mostly of rock and water ice. The greater the rock-to-ice ratio — the more rock it contains — the greater the object's density. The densest moon in the outer solar system — Jupiter's Io — has a density of 3.6 grams per cubic centimeter and is all rock, with no water ice. (Water has a density of 1 g/cm^3.) In contrast, Saturn's moon Mimas has a density of 1.2 g/cm^3 and is mostly water ice, with little rock.

Titan and Triton lie between these two extremes, indicating that each world contains both rock and water ice. Saturn's Titan has a density of 1.9 g/cm^3; Neptune's Triton has a density of 2.1 g/cm^3. Because Titan's density is lower, it also has a lower rock-to-ice ratio. Scientists estimate that rock accounts for 50 to 55 percent of Titan's mass but 70 to 75 percent of Triton's.

McKinnon also points out the different sizes of Titan and Triton. "Titan is a very big world, comparable in size to Ganymede and Callisto," he says. Indeed, Titan is bigger than the planet Mercury and nearly twice as big as Triton: Titan is 5,150 km across, whereas Triton is 2,700 km across.

Robert Brown, who along with Cruikshank was part of the team that discovered nitrogen on Triton, points out other differences. "They are two objects besides Earth that have nitrogen atmospheres," he says, "but the nitrogen inventory on Titan is probably vastly larger than it is on Triton."

That leads him to confront the question of Titan-Triton interchangeability. "If you placed Titan in orbit around Neptune, it's not clear just how similar it would end up looking to Triton," he says. "Yes, if you pulled Triton into an orbit around Saturn you'd end up with an atmosphere, but it's not clear how thick it would be."

As thick as Titan's? "I don't think so," he says. "The answer to that question is still uncertain, because we just don't know what the global inventory of nitrogen is on Triton."

Cruikshank agrees that Triton's nitrogen abundance is unknown: "We don't even know to within a factor of ten thousand. It could be meters thick, or it could be just a very superficial layer that's centimeters thick. I don't happen to think it's that thin; more likely it's meters thick. But not knowing the abundance means that we can't answer that question."

Different Lives

The two moons have had radically different histories. Titan formed in the conventional way with most of Saturn's other satellites, condensing and accreting in a disk surrounding Saturn. It emerged from this disk as Saturn's biggest satellite and has remained in orbit about Saturn, relatively undisturbed, ever since.

In contrast, says Cruikshank, "Triton has clearly been subject to a lot of abuse." Triton probably did not form with Neptune but instead was captured by it. McKinnon agrees: "Triton, in most people's thinking, was a captured planetesimal that underwent severe tidal heating as it settled into its present orbit around Neptune."

The Voyager images of Triton, with a maximum resolution of 400 meters per pixel, show a perplexing multiplicity of types of terrain on Triton. Clearly the moon has been through a lot. Smooth, low-elevation plains, fractured "cantaloupe terrain," ancient flow valleys, many impact craters, recent volcanic activity, and dissimilar terrains overlapping each other make it clear that something beyond the normal planetary surface activities have occurred on Triton.

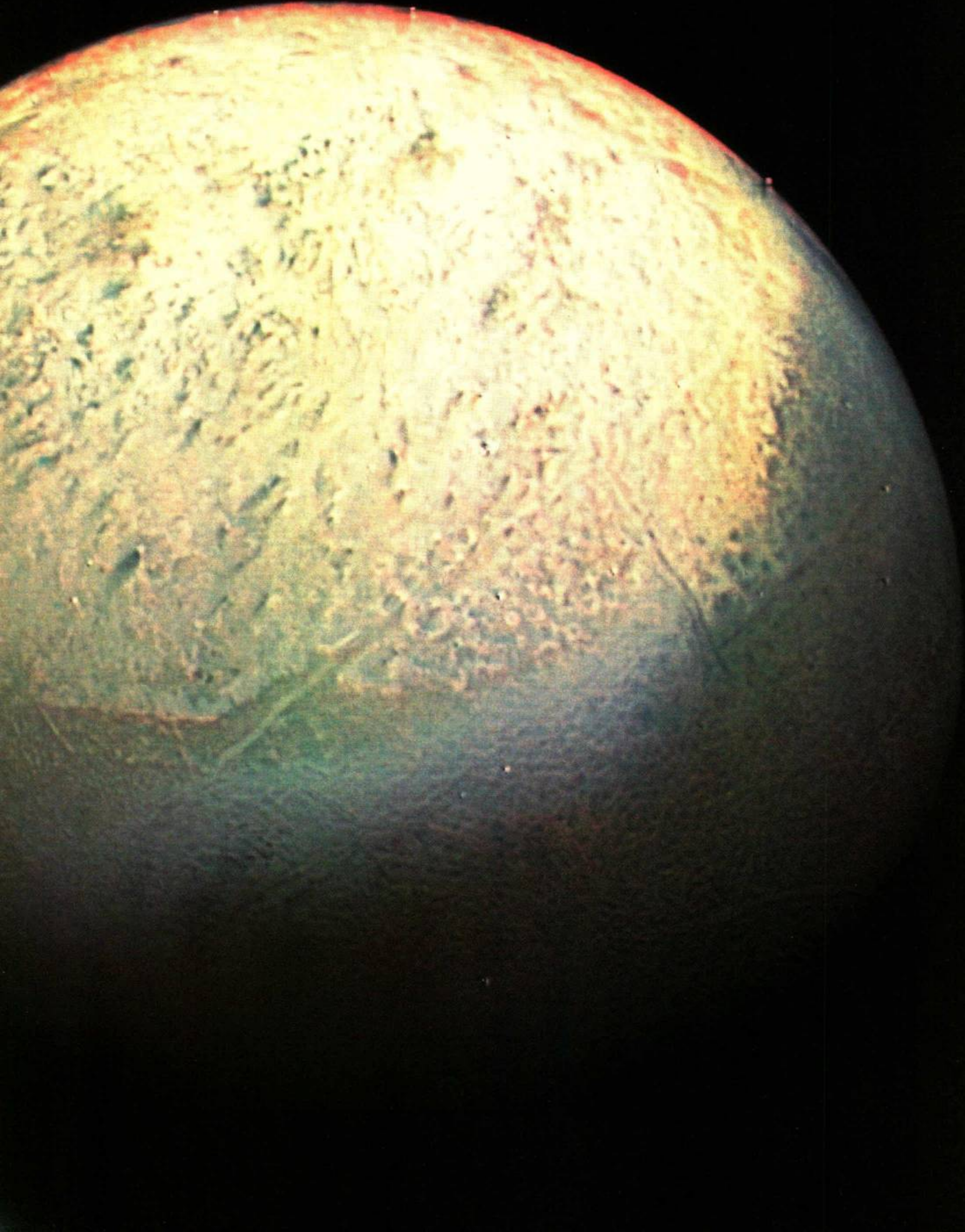
But a stronger clue suggesting that Triton was captured is its strange orbit around Neptune. It orbits Neptune backward — that is, clockwise as viewed from north of the solar system — unlike every planet and most other moons. In fact, of the solar system's 61 known moons, only six revolve clockwise. Triton is the only big moon to do so. On dynamical grounds the backward orbit makes it virtually impossible that Triton formed in the normal way.

Another clue to the different origins of Titan and Triton is their rock-to-ice ratios. If a satellite formed in the warm disk surrounding its planet, as Titan did, it should have a low rock-to-ice ratio. In such warm conditions, carbon joins hydrogen to make methane and nitrogen combines with hydrogen to make ammonia (NH_3). This leaves oxygen free to join hydrogen and create water (H_2O), leading to lots of water ice relative to rock.

In contrast, in a cold region, methane and ammonia do not form. Instead, carbon is bound with oxygen into carbon monoxide (CO), preventing the oxygen from creating as much water as it otherwise would. So an object that arose in a cold part of the outer solar system, away from a giant planet, would inherit less water and have a high rock-to-ice ratio, as Triton does.

Another distant world resembles Titan and Triton, and it too may yield clues to the formation of the outer

ASTRONOMY: Steven G. Davis, NASA/JPL



LACKING THE THICK ATMOSPHERE present on Titan, Neptune's Triton nevertheless is strikingly similar to the Saturnian moon. Differences between Titan and Triton are chiefly due to different temperatures. The two objects, along with Pluto, may hold clues to the fundamental nature and history of the outer solar system.

NASA/JPL

solar system. Unlike Titan, it formed far from any planet; unlike Triton, it was never captured by a planet and has changed little since its birth. But like Titan and Triton, this remote world has methane, an atmosphere, and lots of nitrogen.

Et Tu, Pluto?

"Pluto should probably be tossed in the same bag," says Cruikshank. In 1976, Cruikshank and colleagues Carl Pilcher and David Morrison discovered methane ice on Pluto, suggesting that Pluto also has at least a thin methane atmosphere. In 1988, Pluto occulted a star, proving that the frigid world does indeed have an atmosphere. And in 1992, a team led by Tobias Owen of the University of Hawaii, which included Cruikshank, found that the main gas in Pluto's atmosphere is nitrogen.

Is the comparison between Triton and Pluto valid? "I think comparisons between Triton and Pluto are valid in the sense that they are bodies of similar size and density. In both cases, we know there is methane on their surfaces and nitrogen in their atmospheres," Brown says. McKinnon agrees, "I definitely think the comparison is valid. Triton's and Pluto's bulk compositions and sizes and positions in the solar system are extremely similar."

During the 1980s astronomers determined Pluto's size and density, which nearly match those of Triton. Pluto's diameter is 2,300 km (versus 2,700 for Triton); its density is 2.1 g/cm^3 (versus 2.07 for Triton). Thus, both Triton and Pluto probably have high rock-to-ice ratios, which strengthens the case that both formed far from any planet.

But Pluto has probably led a quieter existence since its formation. Indeed, one reason astronomers want to see Pluto's surface is that it, unlike Triton, probably preserves a more pristine record of the outermost solar system. Pluto may be what Triton could have been, had Triton eluded Neptune's grasp and the geological activity the satellite experienced following capture.

Pluto may also shed light on the nature of Titan and Triton, and, in particular, why they have nitrogen. Two competing ideas now exist. One is that the nitrogen is primordial — that is, it was trapped in the ices from which Titan and Triton formed. Over time, this nitrogen escaped the satellites' interiors, perhaps through volcanism. The second idea is that the nitrogen now in Titan's atmosphere and on Triton's surface was originally bound with hydrogen in the form of ammonia. Sunlight split the ammonia into nitrogen and hydrogen; the hydrogen, a low-mass gas, escaped, leaving the nitrogen behind.

"Pluto may hold the key to it," says Cruikshank. "Because of its tortured past, Triton probably does not preserve the information that we need to answer this question."

"It's unlikely that anything we see on Triton is truly primordial," McKinnon says. "Triton is a highly processed world. Its surface has been worked on by a number of forces so that it has changed radically over solar system history." Though Triton presently has nitrogen rather than ammonia, that doesn't mean it started out with nitrogen. Instead, it could have begun with ammonia and converted it to nitrogen as the moon was heated.

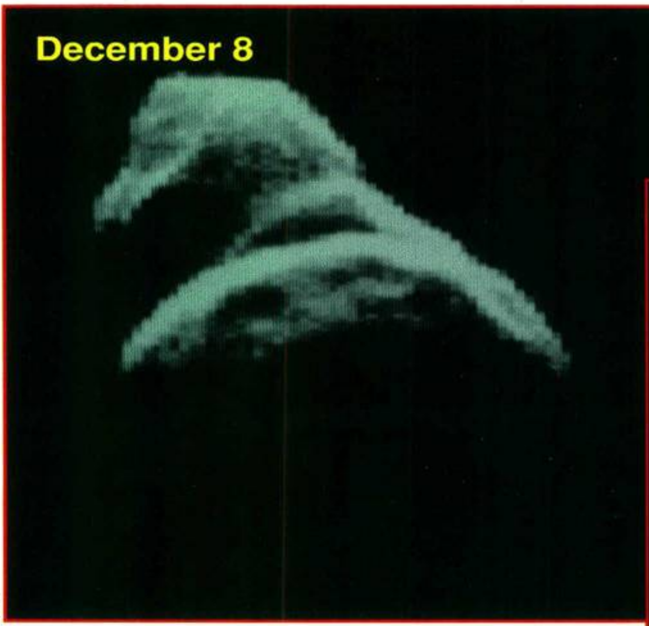
In contrast, "Pluto has probably been left alone in a more nearly frozen state," says Cruikshank. "So if you go to Pluto and you don't find any ammonia, I think we can probably conclude that there isn't any ammonia there and never has been, because what you see is what has been preserved since the origin of the object — unless we get there and find that it's had all kinds of horrible things happen to it."

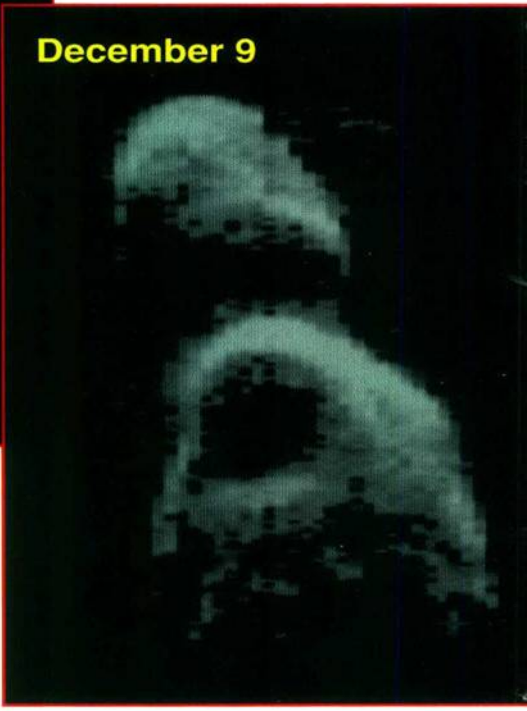
Untangling Distant Worlds

These three worlds may have cousins. Alan Stern of the Southwest Research Institute has proposed that the outer solar system may have once contained hundreds or even thousands of objects similar to Triton and Pluto. (See "Where Has Pluto's Family Gone?" by Alan Stern, September 1992.) And last year astronomers identified a distant object beyond Pluto, $1992QB_1$, that may be related to these worlds.

Future spacecraft missions promise further insight into the relationships among Titan, Triton, and Pluto. Says Cruikshank, "Because of our plans for the continued exploration of the outer solar system, I think the comparison is going to draw much more interest in the years to come." ☐

Ken Croswell is an astronomer in Berkeley, California, who writes frequently for Astronomy. *His last article was "Have Astronomers Solved the Quasar Enigma?" in the February 1993 issue.*





JPL

To a person in the street, radar usually summons visions of weather reports, air traffic control, or speeding tickets. But astronomers use radar too, though for decidedly more esoteric reasons. Radar has allowed astronomers to image the surface of the cloud-covered planet Venus and to resolve a few asteroids that have strayed near Earth. And when the asteroid 4179 Toutatis passed within 3.6 million kilometers of Earth last December, radar provided remarkable close-up views that showed just how strange this object is.

Toutatis (pronounced too-TAT-is) turned out to be a contact binary, meaning that it consists of two originally separate parts that have been joined together. Imagine two giant, irregular boulders that at some time in the distant past collided softly, so softly that instead of destroying one another they gently fused together. Astronomers think this is how the lumpy, oblong Toutatis formed, though the details of where the two bodies originated, how they collided, and what put the resulting contact binary in an orbit that periodically brings it close to Earth remain unknown.

"The binary nature of Toutatis is the most important single result of the radar experiment."

"The binary nature of Toutatis is the most important single result of the radar experiment," according to Steven Ostro, an astronomer at the Jet Propulsion Laboratory and leader of the radar team. The images show the two parts of Toutatis to be irregularly shaped and pocked with craters a few hundred meters across. And the strength of the returned radar signal reveals that the surface is rough at a scale of a few centimeters and strewn with considerable dust. The larger body averages about 4 kilometers in diameter and the smaller one about 2.5 kilometers. The combined object rotates with a period between 10 and 11 days, the third-longest rotation period known for any asteroid.

Ostro and his team imaged Toutatis from the Goldstone Deep Space Communications Complex in California's Mojave Desert. Using the 70-meter dish, they beamed a 400,000-watt coded radio transmission at Toutatis. The returning echoes were picked up by the new 34-meter antenna, which relayed them to the 70-meter station where they were decoded and processed into images. Further processing over the coming months should reveal surface features less than 100 meters across.

An Important First

Toutatis is only the second asteroid viewed at close range. The first was 951 Gaspra, which the Galileo spacecraft photographed in October 1991 (see "Galileo Views Gaspra," February 1992, and "Gaspra Surprises Astronomers" in this month's AstroNews). However, Toutatis is the first near-Earth asteroid seen in detail. Though literally thousands of small objects sail through the solar system on orbits that cross Earth's orbit, Toutatis is the only one that both passed very close to our planet and was well-known before it did so, allowing astronomers to plan extensive observations. In addition to the radar measurements, ground-based telescopes and the Hubble Space Telescope observed Toutatis around its closest approach and that data should be analyzed within a few months.

Radar images of a few other near-Earth asteroids contained hints that some might be contact binaries. The best evidence came from observations of 4769 Castalia, originally called 1989 PB, which showed that the object consisted of two 1-km-wide lobes but were much too crude to reveal any surface details. (See "Radar Reveals a Double Asteroid," April 1990.)

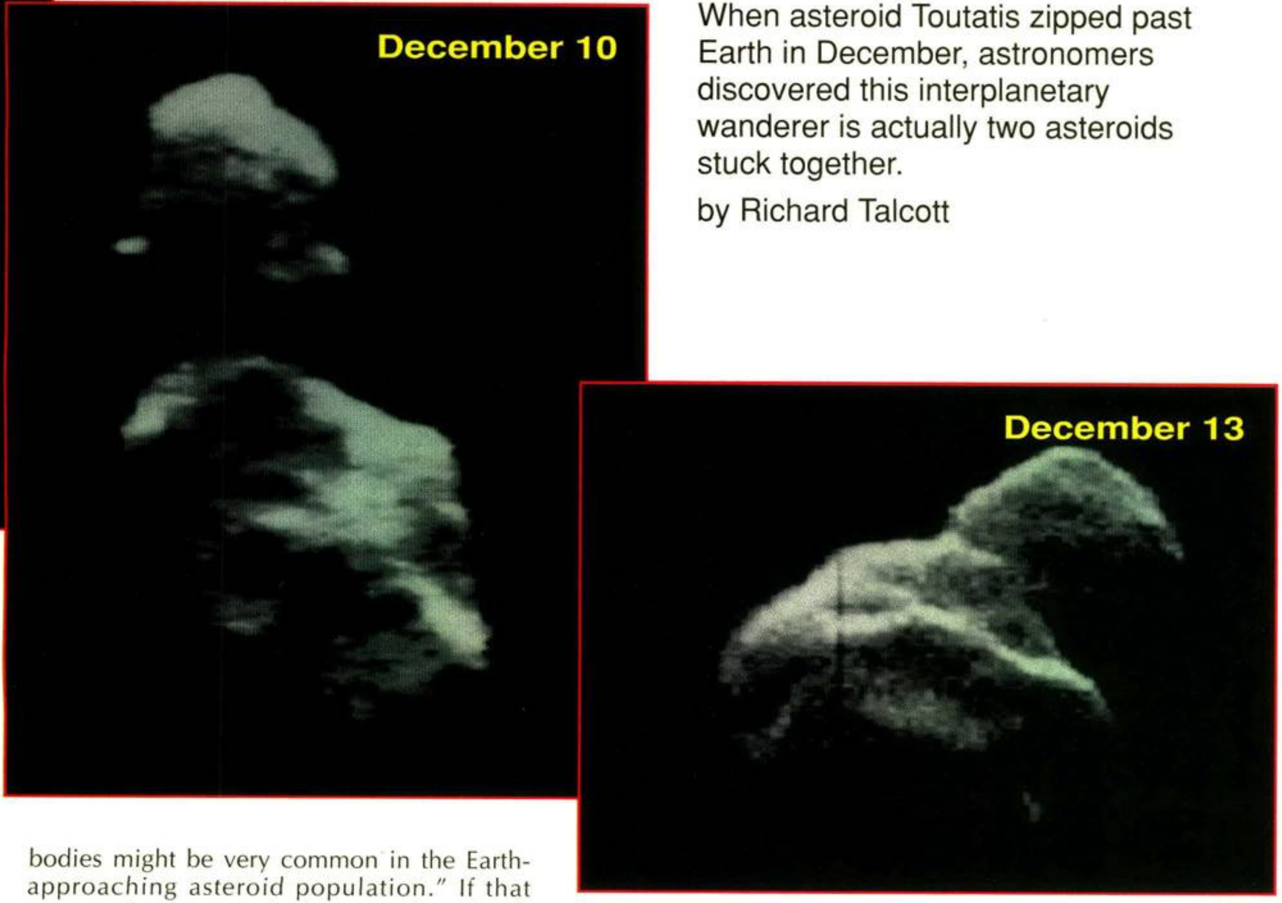
"Four years ago we were startled by the initial evidence for contact-binary asteroids" among the near-Earth asteroids, says Ostro. "Now it seems that double

TOUTATIS

SEEN WITH RADAR

When asteroid Toutatis zipped past Earth in December, astronomers discovered this interplanetary wanderer is actually two asteroids stuck together.

by Richard Talcott



FOUR RADAR VIEWS OF TOUTATIS near closest approach show the two huge rocks that form the contact-binary system. The radar illumination comes from the top of the page, so parts of each component facing toward the bottom can't be seen. The changing orientation results from the asteroid's slow rotation and the changing viewing angle as the asteroid flew past Earth.

bodies might be very common in the Earth-approaching asteroid population." If that proves to be the case, the large number of such objects would provide important clues to how the near-Earth asteroids formed and later evolved. One such inference, according to Ostro, is that many asteroids orbiting in the asteroid belt between Mars and Jupiter may suffer gentle, non-catastrophic collisions that end up injecting them into orbits that pass through the inner solar system.

How did Toutatis itself come to be? Though little doubt exists that a soft collision fused the object's two lobes together, the circumstances leading up to that collision and the asteroid's subsequent evolution remain mysteries. Ostro speculates that "Toutatis may be two pieces of a much larger asteroid that once orbited in the main asteroid belt, and which was disrupted in a catastrophic collision with another large object." Those two pieces then collided, fusing together.

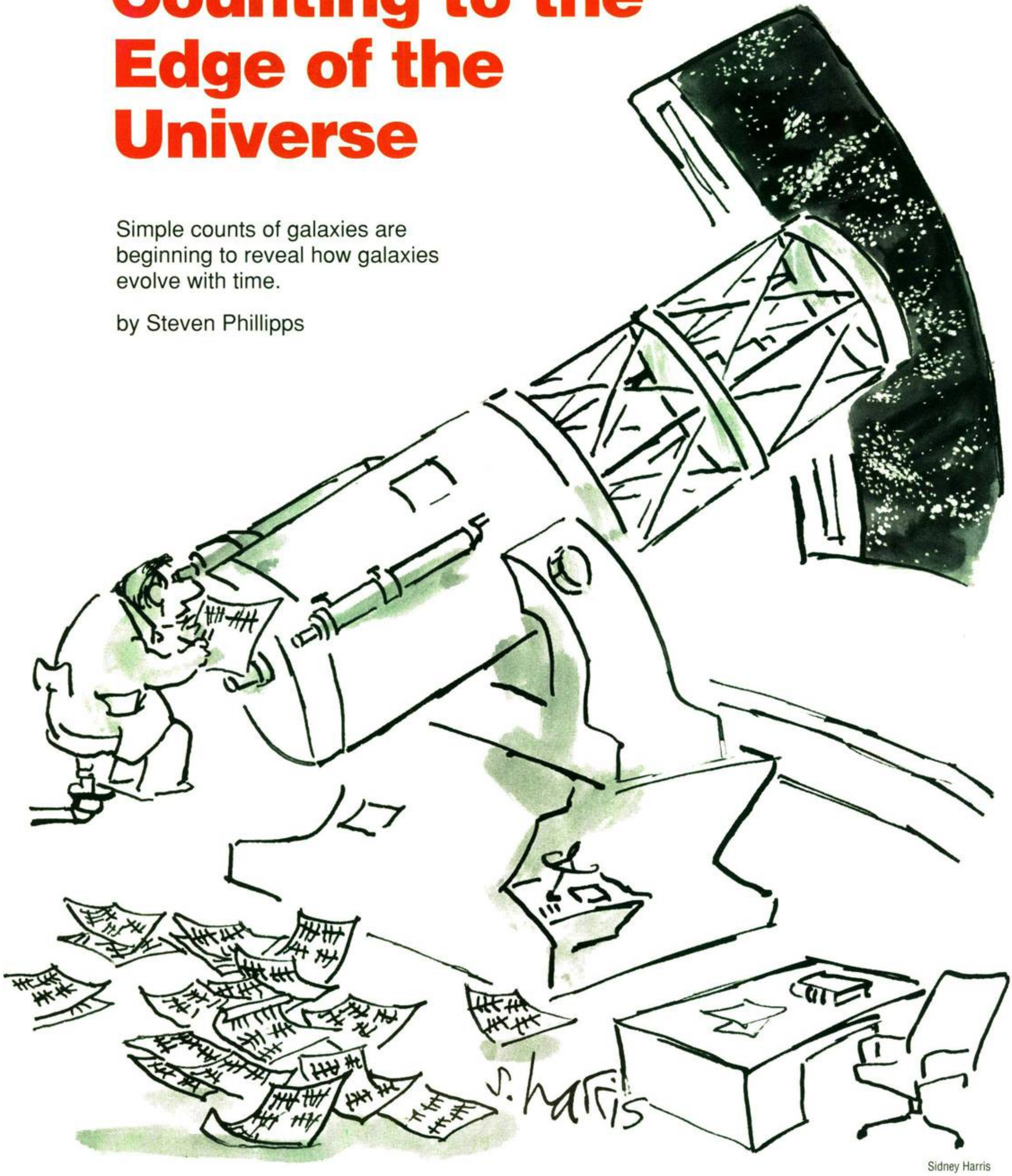
The key to learning whether the two pieces once belonged to the same object or to different objects is to send a spacecraft to rendezvous, land, and return samples from both components of the asteroid. If the samples have the same composition, then the two parts most likely belonged to a single parent body. If the compositions are markedly different, the parts came from different parents.

The possibility of a sample-return mission to Toutatis is not all that far-fetched. Astronomers are looking at dozens of possible targets for such a mission to a near-Earth asteroid, and Toutatis is one under consideration. If we ever do send a spacecraft to Toutatis, we may learn how this remarkable object came to be and how it ended up in an orbit that allows us to learn its secrets. □

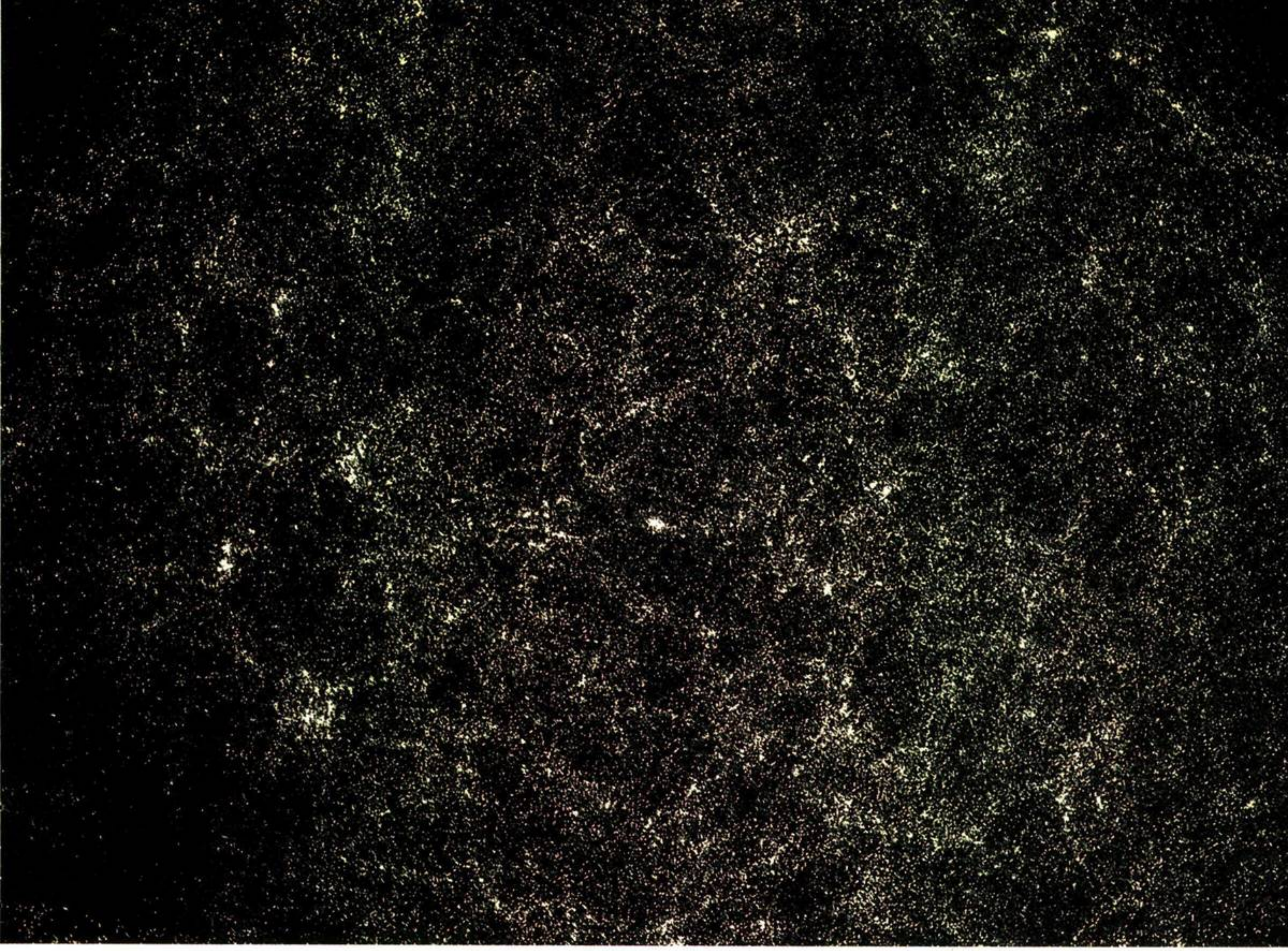
Counting to the Edge of the Universe

Simple counts of galaxies are beginning to reveal how galaxies evolve with time.

by Steven Phillipps



Sidney Harris



M. Seldner, B. L. Siebers, E. J. Groth, and P. J. E. Peebles

ONE MILLION GALAXIES cover this plot of galaxy counts in the northern hemisphere. The Coma cluster of galaxies appears as a bright group of dots at the center.

Counting galaxies is as easy as . . . well, 1, 2, 3. But despite their simplicity, counts are a rich source of information providing astronomers with insight into the structure of the universe and how galaxies formed and changed with time. From counts they can tell whether galaxies are scattered uniformly through space and whether ancient collisions and mergers of galaxies have affected the numbers of galaxies.

As simple as counting galaxies is, it is a relatively new technique. For one thing, any useful count must extend to faint galaxies. In the 18th and 19th centuries, larger telescopes helped astronomers such as William and John Herschel to see about 1,000 galaxies, or nebulae as they were known then. The observations of bright galaxies by the Herschels and others were collected by John Dreyer into the *New General Catalogue*. But these impromptu samplings of galaxies contain too few galaxies for any meaningful interpretation of the observed numbers of galaxies seen in different areas of the sky.

After he showed that "spiral nebulae" were in fact galaxies like our own, Edwin Hubble counted galaxies in the 1930s, using the 100-inch Hooker telescope at Mount Wilson. Although Hubble detected galaxies as faint as magnitude 20, he could not unravel the information contained in his counts of faint galaxies.

Astronomers now know that Hubble's data were affected by the curvature of the universe — ironically one of the characteristics that galaxy counts can help determine. After Hubble, galaxy counts largely languished until the 1970s, when astronomers learned how to apply them to studies of the universe.

Making Galaxy Counts

Beatrice Tinsley of the University of Texas resurrected the counting of faint galaxies when she discovered how to interpret cosmological effects contained in counts. Coincidentally, the 1970s saw the construction of a number of wide-field Schmidt telescopes and large telescopes 4 meters or more in diameter. New surveys could reach 22nd magnitude using Schmidt telescopes or 24th magnitude using 4-meter-class telescopes.

However, astronomers don't sit at a telescope and tick off galaxies as the poor soul is doing in the Sidney Harris cartoon, nor do they peer at photographic plates obtained with the telescope. The drudgery of inspecting plates, deciding which objects are galaxies, and then counting the galaxies is now the work of computer-controlled plate scanning machines. Two such machines, APM at Cambridge University in England and COSMOS at the Royal Observatory, Edinburgh, can measure hundreds of thousands of images on a plate in just a few hours.

But the ability to count isn't enough. The count must be done in a fruitful manner. We can't just count

National Optical Astronomy Observatories

COUNTING NEARBY GALAXIES provides a baseline for counts of distant galaxies. Even small, faint galaxies show up easily in photos of nearby galaxy groups.

all galaxies, because galaxies come in all sizes, brightnesses, and distances. More-distant galaxies also appear younger because light from the galaxy takes a longer time to reach us. The farther away the galaxy is, the longer ago its light must have left to reach us. So we look back in time as we look at distant galaxies.

Because of this look-back time, a count of all galaxies mixes up the effects of galactic changes with time and the distribution of galaxies at different distances. To help separate these two effects, astronomers count down to the same limiting magnitude in each area of sky.

Most conventional models of the universe assume that the universe is homogeneous on large scales; that is it looks the same from wherever you observe. In particular, the number of galaxies in each volume of space should be the same everywhere. So no matter what direction you look, you should see the same number of galaxies per square degree of sky (ignoring the effect of obscuring gas and dust that may block our view of some galaxies).

Counts were made by Harlow Shapley in the 1930s down to 14th magnitude and, as mentioned above, by Hubble down to 20th magnitude. These and more modern counts indicate that galaxies scatter uniformly across the sky. Maps show clusters of galaxies and large voids, where no galaxies seem to lie, on small scales. (See the plot of galaxies on the previous page.) But on large scales — the ones of cosmological interest — galaxies do appear scattered uniformly.

Galaxy counts can also show if galaxies have changed with time — in astronomers' parlance, evolved. Astronomers look for evolution by comparing the numbers of galaxies as the limiting magnitude grows fainter. Because galaxies are uniformly scattered, they should appear at the same rate as fainter, and therefore more-distant, galaxies are counted. A change in the number implies that galaxies have somehow changed.

Fainter is More

Imagine that all galaxies have the same luminosity. The galaxies won't all appear the same brightness because they lie at different distances. This is because light dims as the square of an object's distance, so a galaxy twice as far away as another appears four times fainter.

At the same time that galaxies appear fainter as distance is increased, the number of galaxies seen in an area of sky grows larger because the volume of space increases. If galaxies of the same luminosity are spread uniformly with distance, then a count of galaxies with apparent magnitude 10 would reveal 4 times the number of galaxies seen at magnitude 9.

A detailed analysis shows that counts for galaxies with different lumi-

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NEARBY COUNTS QUADRUPLE as the limiting magnitude grows fainter. Early counts by Shapley and Hubble showed that on a large scale galaxies are scattered uniformly through the universe.

nosities change with distance in the same way.

The counts by Shapley and Hubble both show that galaxies are scattered uniformly not only across the sky, but also with distance. This supports the assumption of cosmological models that the universe is homogeneous. However, the counts by Shapley and Hubble didn't go very far into the universe, concentrating instead on bright nearby galaxies.

Cosmological effects come into play when observing distant galaxies. This is a double-edged sword: these effects make galaxy counts useful for testing different cosmological models but at the same time make interpreting the counts difficult. For example, the change in galaxy count with distance is different for a so-called flat universe that has normal three-dimensional geometry — what scientists call Euclidean space — than it is for a curved, or non-Euclidean, universe.

In a non-Euclidean universe, the three space dimensions do not lie at right angles to one another. The gravity of the matter in the universe causes space to distort just as a black hole distorts the space around it. Depending upon its mass, the universe can be flat, curved open, or curved closed. An open universe will expand forever while a closed universe will eventually stop expanding and collapse upon itself. In a flat universe, as we've said, galaxy counts increase four times as the limiting magnitude grows fainter. In an open universe, counts increase more quickly because of the curvature, and in a closed universe they increase more slowly, again because of the curvature.

Astronomers count many more galaxies than cosmological models have predicted.

From recent counts that extend down to magnitude 24, researchers have found that the numbers of galaxies don't quadruple with each step in limiting magnitude — they only triple. However, these results do not suggest that the universe is closed, because evolutionary effects combine with the effects caused by curvature of the universe.

At first, separating the changes caused by galactic evolution from those of the structure of the universe proved daunting to astronomers. Then Tinsley showed that the major factor controlling the counts of faint galaxies is the evolution of the galaxies themselves, not cosmological factors describing the geometry of the universe. Deviations in the galaxy counts due to the curvature of the universe are small, but evolution can affect greatly the visibility of distant galaxies and thus the galaxy counts.

Two types of evolution in galaxies are important. The first is the simple fading with time of the original stellar population in the galaxy as brighter

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DISTANT GALAXY COUNTS TRIPLE with each step in limiting magnitude. But changes in galaxies with time affect these counts, so the counts do not directly reveal the structure of the universe.

stars reach the ends of their lives. The second is due to the change in the rate at which new stars are formed; usually the rate of star formation decreases with time. But separating the effects of evolution and curvature is not an easy task. Two other observational effects come into play when astronomers survey faint galaxies.

Looking at Distant Galaxies

Most galaxies appear to move away from the Milky Way because of the expansion of the universe. As Hubble showed, the expansion causes a galaxy's spectrum to shift to the red by an amount proportional to its distance. Distant galaxies show a larger redshift than nearby galaxies.

Redshifting causes a problem with galaxy brightness. To measure brightness consistently, astronomers measure the light from galaxies at one wavelength, say the blue. This works fine for a nearby galaxy, but for a distant one, its blue light has shifted to the green or yellow part of the spectrum. The galaxy originally emitted what a researcher sees as blue light in the ultraviolet. Because galactic stars emit different amounts of light in the blue and ultraviolet, astronomers must correct the measured brightness of a galaxy for its redshift.

The second observational effect involves the luminosity of the galaxy itself. Luminous galaxies are easier to see at greater distances than intrinsically faint ones, so cosmological factors affect luminous galaxies more. As a result, galaxy counts differ for galaxies of different luminosity and they will change differently with distance. Therefore, unlike the case for simple Euclidean space, counts of galaxies with different luminosities cannot simply be added together to construct a total galaxy count.

To predict what the total count should be, astronomers need to know the number of bright galaxies compared to faint ones, the so-called luminosity function. If most of the galaxies are intrinsically faint and nearby, then cosmological factors are unimportant. Galaxy counts would increase by a factor of four as the distance decreased by a factor of 1.6 (ignoring evolutionary effects). But if a large number of galaxies are intrinsically bright and visible at large distances, then cosmological factors such as curvature dominate the count.

Deep Counts

Researchers have found that models of the galaxy population incorporating cosmological effects — "no evolution" models because they ignore galactic evolution — predict galaxy counts that do not even triple with distance. Compared with the observed counts, this implies that more galaxies than expected were detected at faint magnitudes. This problem became worse with the introduction of new CCD detectors.

Tony Tyson of the Bell Labs extended the counts to magnitude 27 or 28, using a CCD at Kitt Peak National Observatory. And Nigel Metcalf, Tom Shanks, and Dick Fong of the University of Durham in England made CCD observations with the Isaac Newton Telescope on La Palma. They looked at a single 3.5 by 5.5 arcminute field. Their image had a total exposure time of 24 hours and was composited from about 50 separate frames taken over the course of three years. The image shows at least 3,000 objects (mostly galaxies) down to magnitude 28. An

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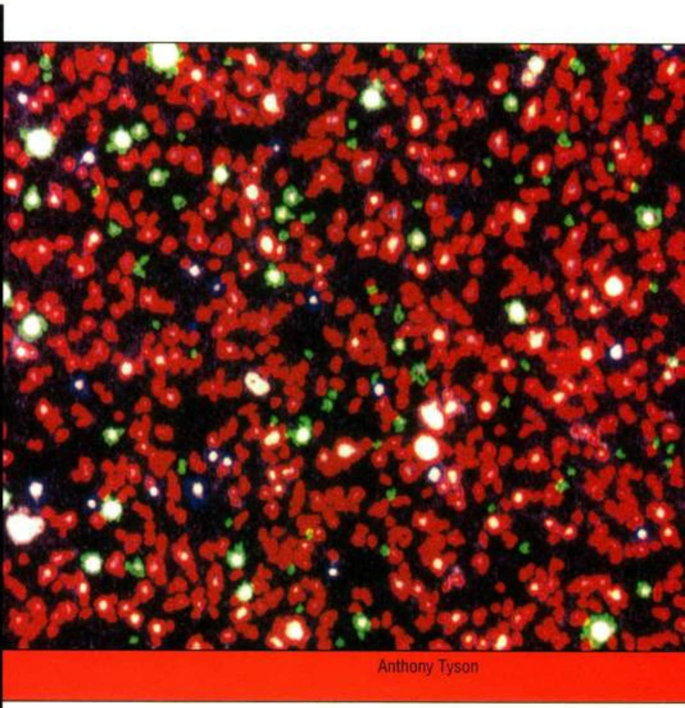


Anthony Tyson

IMAGES OF FAINT GALAXIES, colored red and blue above, suggest that some galaxies must dim drastically over time. Perhaps today's dwarf galaxies weren't always so modest.

equivalent image of one square degree would contain over half a million galaxies.

The CCD frames by Tyson and the Durham group indicate that model predictions of galaxy numbers fall short of the numbers actually observed by a large factor. In particular, Tyson's counts continued to triple with fainter limiting magnitudes, while models predict a slower increase in numbers of galaxies.

An obvious explanation of this discrepancy is that galaxies were brighter when the universe was younger. Bright blue stars in young galaxies brightened distant galaxies, making them easier to see in faint galaxy counts. But the redshifts for galaxies as faint as magnitude 22.5 suggest this explanation is wrong. If a large number of bright galaxies existed at great distances, then astronomers should have observed a large *number of high redshifts*. But the redshifts were similar to those of models that predicted no evolution.

Yet undoubtedly galaxies evolve. Several scenarios may reconcile observations and model predictions. One possibility is that present observations preferentially detect certain types of galaxies. Galaxies with bursts of star formation would have temporarily high surface brightnesses or high brightness per unit area across the sky. Surveys detect galaxies with intrinsically high surface brightness more easily at great distances than they do galaxies with normal surface brightness. In fact, normal galaxies may be dimmed out of sight. But if star bursts occurred only a long time ago, faint galaxy counts would contain a large number of these galaxies compared to counts of nearby galaxies, making the observed counts appear higher than model predictions.

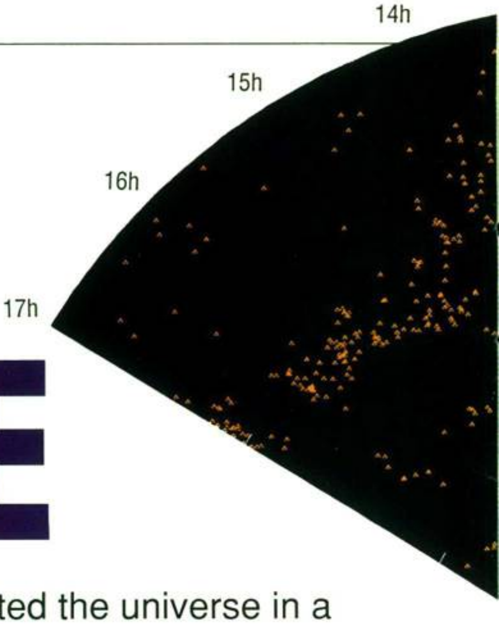
Or perhaps the galaxies seen in faint counts are not the direct precursors of today's galaxies at all. Multiple mergers may have combined these galaxies to form the giant galaxies seen in nearby clusters. Recent observations with the Hubble Space Telescope show that a greater percentage of spirals exists in distant galaxy clusters than in nearby clusters. (See AstroNews in the March issue.) The bright spirals contribute to the high counts at a distance, but later mergers reduce the number of spirals to the percentage seen in nearby clusters.

Distant galaxies may not be the direct precursors of today's galaxies.

Despite the power of galaxy counts in uncovering information about the universe, cosmological effects and galactic evolution presently prevent astronomers from using counts to determine the curvature of the universe. Three lines of attack may change the usefulness of counts. One is a better determination of the luminosity function and the role of low-surface-brightness galaxies in galaxy clusters. And more observations from the Hubble Space Telescope of distant clusters will show the importance of mergers and collisions.

But an unlikely source may provide the third and most profitable line — faint galaxies. Their large numbers, effect on the luminosity function, probable large changes in brightness with time, and role in galactic mergers make these tiny galaxies mighty in the universe. They may rule the universe and their observation may someday lead astronomers to knowing its fate. ☐

Steven Phillipps, astronomer at the College of Cardiff of the University of Wales, counts galaxies in nearby clusters and searches for galaxies with low surface brightness.



A New Map of the UNIVERSE

Astronomers have circumnavigated the universe in a project to map the structure of deep space.

by Alan Dyer

Imagine flying a billion light-years straight up out of the plane of the Milky Way. Our home Galaxy is now just a point in the distance surrounded by the specks of thousands of other galaxies. What does the universe look like from this perspective? Perhaps something like what we see in a new map produced by John Huchra, Margaret Geller, and Ron Marzke at the Harvard-Smithsonian Center for Astrophysics.

Their circular chart (opposite) plots the positions of more than 14,000 galaxies in a sweeping circle of space with us at dead center. The map encompasses a volume of the universe that extends 500 million light-years from Earth. By comparison the nearest large galaxy to ours, the Andromeda Galaxy, is 2 million light-years away. The most distant galaxies and quasars seen yet are 5 to 10 billion light-years away, roughly 10 to 20 times beyond the outer boundary of the new map.

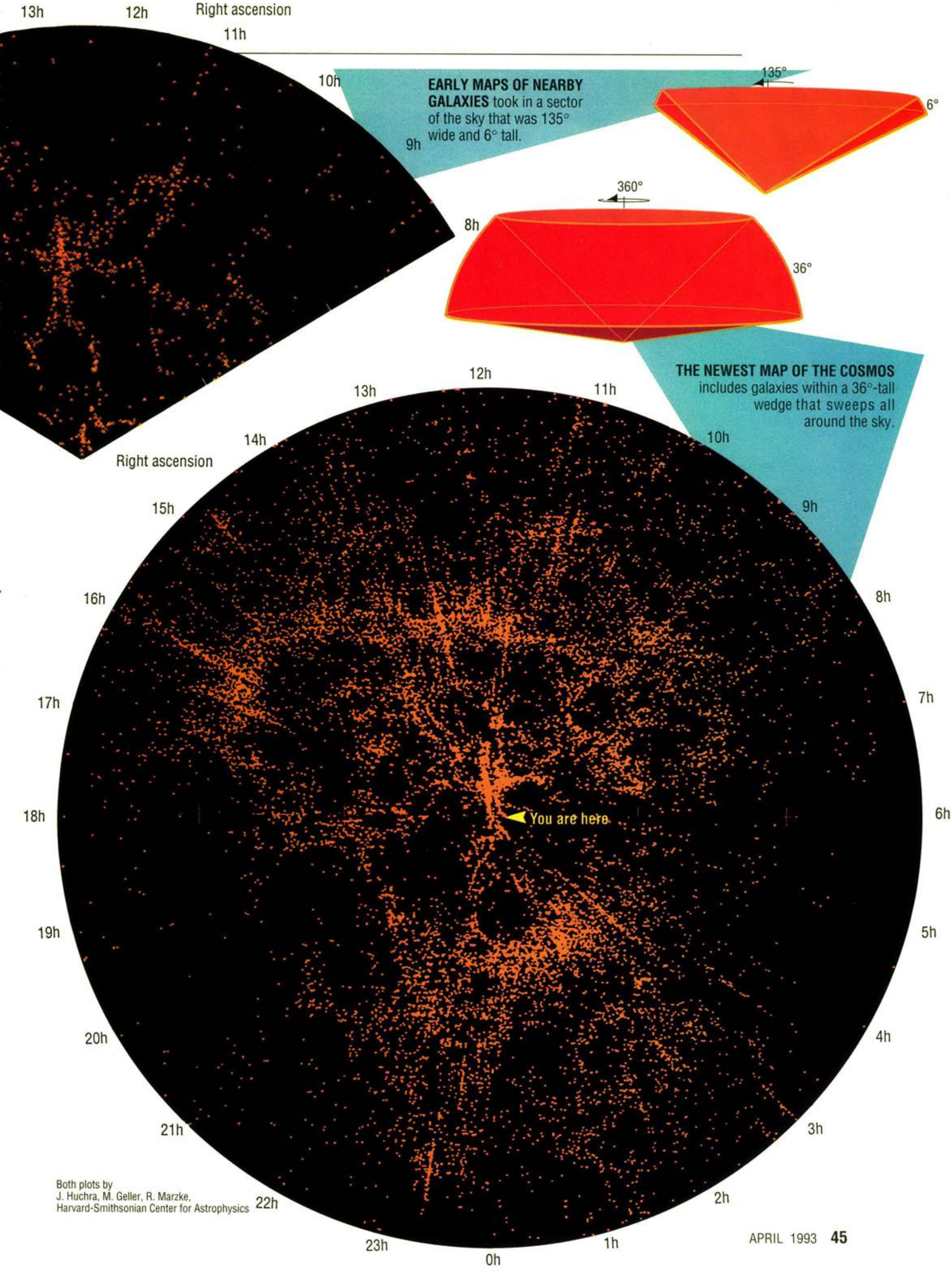
Since 1985 the team has been mapping all the galaxies near us in space. They started with several 135°-wide by 6°-tall strips across the northern spring sky, surveys that produced the "wedge" style of maps such as the one shown above. They have now extended the survey completely around the sky. The latest map takes in all nearby galaxies within a swath that is 360° wide by 36° tall and extends from 8.5° north declination up to 44.5° north. If this were a map of Earth's surface, it would be like charting the surface all around the globe from a latitude of Panama north to Minneapolis.

The most striking feature of the all-sky plot is that it looks as if galaxies are lined up along spokes aimed directly at Earth. This "fingers of God" effect isn't real, however. How far a galaxy is away from the map's center is technically a measure of a galaxy's redshift, not distance. When a galaxy is moving away from us, its light waves become shifted to the red end of the spectrum. On the grand galactic scale of things, all galaxies are moving away from each other because of the expansion of space from the force of the big bang. The farther a galaxy is away from us, the faster it appears to be moving and the greater its redshift.

Therefore, redshift is more or less equivalent to distance. However, in the case of a tight cluster of galaxies, the member galaxies will be about the same distance from us but may have slightly different redshifts. This is because the galaxies are moving locally around the center of the cluster, motions that add or subtract from their redshift caused by the expansion of the universe. The resulting smearing of redshifts shows up as the radial spokes.

However, other features are real. In the top half of the plot, you can see the so-called "great wall" of galaxies extending from 9 hours right ascension to 16 hours across the northern spring sky. The bright streak just above our location is the Virgo Cluster, a rich, nearby galaxy cluster well known to amateur astronomers as the home of many Messier objects. The streak above it at roughly 13 hours is the Coma Cluster, also known as Abell 1656. The clumping of galaxies in the bottom half from 23 hours to over 3.5 hours is the Pisces-Perseus Chain of galaxy clusters that dominates the northern autumn sky. The most prominent streak in that area (at 3 hours 16 minutes) is the cluster Abell 426. The two empty regions toward 6 and 19 hours are zones where our view to distant galaxies is blocked by the spiral arms of our own Milky Way Galaxy. Other circular empty regions, however, are thought to be real and give the universe on the grandest scale a soap bubble appearance. Why galaxies should congregate around the perimeters of empty voids is one of the mysteries that has cosmologists hard at work.

Meanwhile, Huchra, Geller, and Marzke are continuing their survey. By 1995 they hope to have completed mapping all galaxies brighter than 15th magnitude that lie in the northern half of the sky. ☐

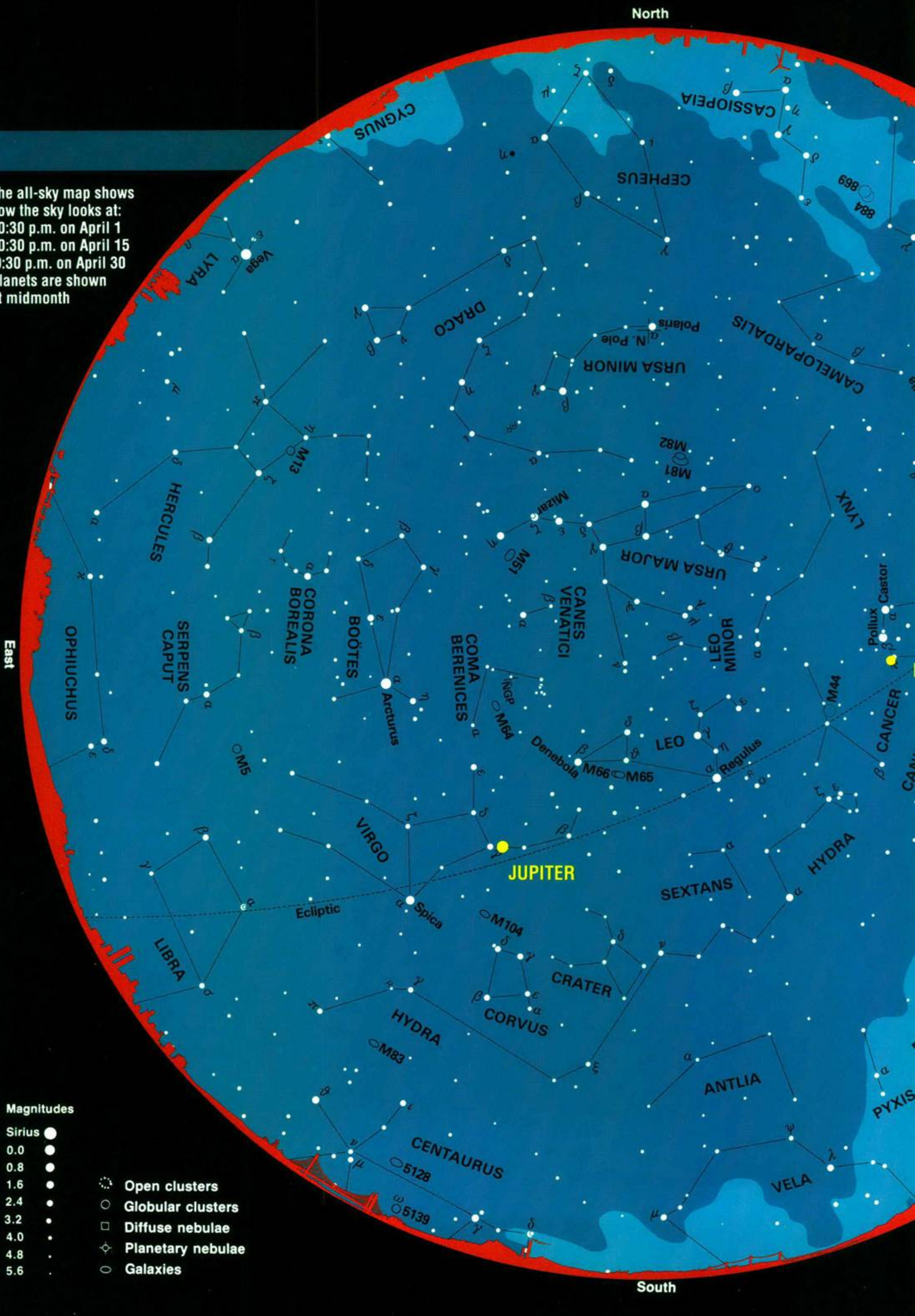


EARLY MAPS OF NEARBY GALAXIES took in a sector of the sky that was 135° wide and 6° tall.

THE NEWEST MAP OF THE COSMOS includes galaxies within a 36°-tall wedge that sweeps all around the sky.

Both plots by
J. Huchra, M. Geller, R. Marzke,
Harvard-Smithsonian Center for Astrophysics

The all-sky map shows how the sky looks at:
10:30 p.m. on April 1
10:30 p.m. on April 15
9:30 p.m. on April 30
Planets are shown at midmonth


North
South
East
CYGNUS
CASSIOPEIA
CEPHEUS
869
884
LYRA
Vega
DRACO
Polaris
N. Pole
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CAMELOPARDALIS
M82
M81
HERCULES
M13
LYNX
Mizar
M51
URSA MAJOR
CORONA BOREALIS
BOÖTES
CANES VENATICI
LEO MINOR
OPHIUCHUS
SERPENS CAPUT
COMA BERENICES
Castor
Pollux
Arcturus
NGP
M64
M44
CANCER
M5
Denebola
LEO
Regulus
M66
M65
VIRGO
JUPITER
HYDRA
SEXTANS
Ecliptic
Spica
LIBRA
M104
CRATER
CORVUS
HYDRA
M83
ANTLIA
PYXIS
CENTAURUS
5128
5139
VELA
Magnitudes
Sirius
0.0
0.8
1.6
2.4
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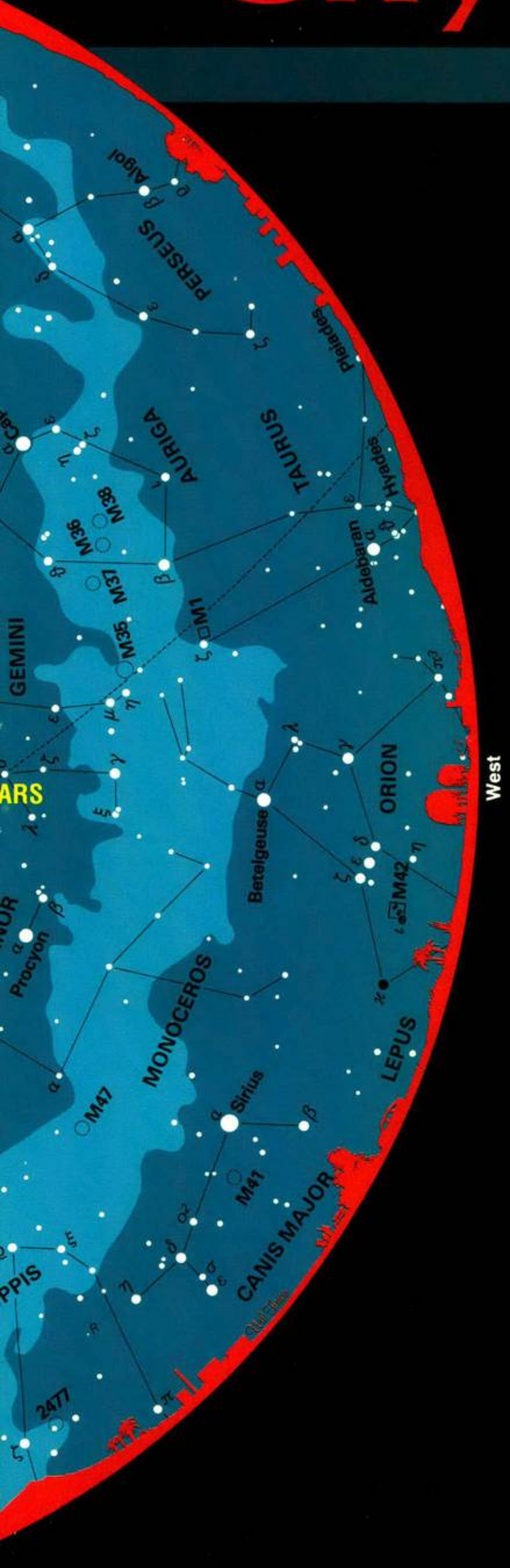
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

April 1993



JUPITER BRILLIANT ALL NIGHT

Jupiter shines brighter than any other point of light in this month's evening sky, overwhelming the stars of its host constellation, Virgo. Jupiter appears in the east as darkness falls and wheels slowly across the sky as the night progresses, setting shortly after morning twilight commences.

THE MOON JOINS VENUS

Venus and a slender crescent Moon are the top attractions on April 19. The two form a striking pair in the eastern sky that morning, lying just a few degrees apart half an hour before the Sun rises. After sunrise the Moon passes in front of Venus, occulting it from view for observers in most of North America.

LYRIDS PEAK ON APRIL 21/22

A New Moon greets observers on the night of April 21/22, providing a dark sky for the annual Lyrid meteor shower. You can expect to see roughly 15 meteors per hour before morning twilight commences on the 22nd and about half that number on the mornings of the 21st and 23rd.

MARS JOINS THE GEMINI TWINS

The Red Planet passes 5° south of Gemini's brightest star, Pollux, on the evening of April 14. For several days around then, you can see 0.8-magnitude Mars near the slightly fainter Pollux and Gemini's other bright star, Castor.

Calendar of Events

1 Venus is in inferior conjunction
5 Mercury is at greatest western elongation (28°)
The Moon is at perigee (222,688 miles from Earth), 3:30 p.m. EDT
6 The Moon passes 7° south of Jupiter, 6 a.m. EDT
Full Moon is at 2:43 p.m. EDT
13 Last Quarter Moon is at 3:39 p.m. EDT
14 Mars passes 5° south of Pollux, 11 a.m. EDT
16 Mercury passes 8° south of Venus, 7 a.m. EDT
The Moon passes 7° north of Saturn, 4 p.m. EDT
18 The Moon is at apogee (252,246 miles from Earth), 1:07 a.m. EDT
19 Venus is occulted by the Moon, 1 p.m. EDT
The Moon passes 8° north of Mercury, midnight EDT
21 New Moon is at 7:49 p.m. EDT
Lyrid meteor shower peaks
25 Asteroid Amphitrite is at opposition
Mars is at aphelion (154.9 million miles from the Sun)
28 The Moon passes 6° south of Mars, 8 p.m. EDT
29 First Quarter Moon is at 8:40 a.m. EDT

Eye on the Sky

by Deborah Byrd

JUPITER DOMINATES THE EVENING SKY

As evening twilight descends this month, scan the eastern sky for the bright planet Jupiter. It lies low in the sky when night falls on April 1 and reaches its highest position in the south shortly after midnight. Then it's only two days past opposition, when Earth passed between Jupiter and the Sun, and one day past its closest approach to Earth for the year. Jupiter remains quite close to Earth throughout April and is very bright, shining at magnitude –2.4. It glows more brilliantly than any star and is surpassed by only Venus and the Moon.

You'll get the chance to see Jupiter and the Moon together on the night of April 5/6, when our satellite lies near the king of planets. It makes sense that the Full Moon passes Jupiter when the planet is nearly opposite the Sun. That's because the Moon appears Full when it, too, is opposite the Sun in our sky.

Jupiter now resides in Virgo. Though this constellation is large and relatively faint, you'll have no problem finding its brightest star, 1st-magnitude Spica. Spica lies about 15° southeast of Jupiter throughout April.

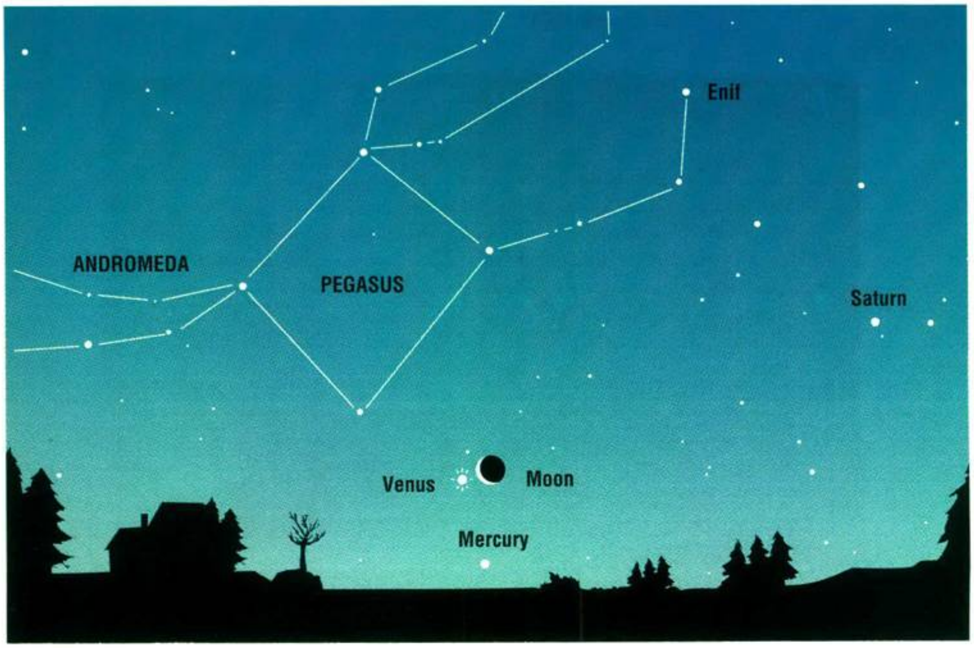
Mack Frost

A SLIM CRESCENT MOON JOINS VENUS in the predawn sky on April 19 (below), recreating the memorable morning scene of August 18, 1990 (above).

THE MOON VISITS VENUS

Early risers can witness the return of Venus to the predawn sky. Venus passes between the Sun and Earth on April 1, when it officially enters the morning sky. But the ecliptic — the apparent path of the Sun, Moon, and planets — makes a shallow angle to the eastern horizon on spring mornings, which keeps Venus low in the sky. Still, Venus is very bright, and it brightens rapidly in April as its lit half turns more in our direction. By the end of the month, Venus shines at magnitude –4.5.

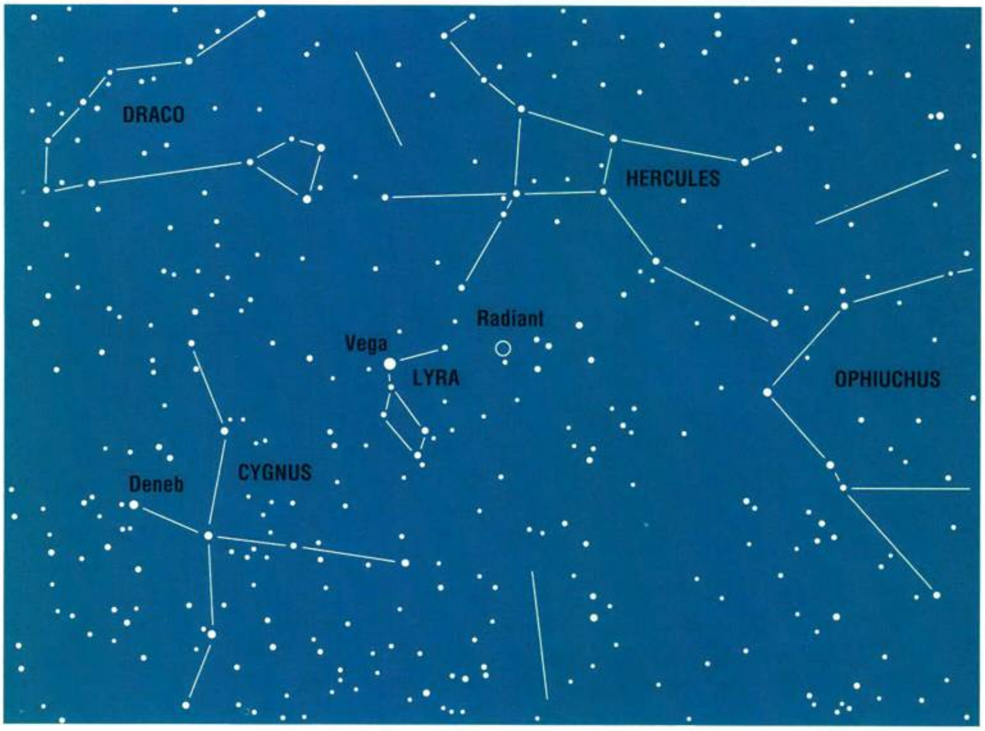
Although Venus lingers near the horizon throughout April, it's bright enough that you should be able to spot it in the east before dawn. A good morning to look is that of April 19, when the planet appears near the waning crescent Moon. For an observer at 40° north latitude, the two appear about 10° high half an hour before sunrise. To see them, you'll need a clear sky and an unobstructed eastern horizon. Later that day, well after the Sun comes up, the Moon occults Venus for observers in much of North America. For details on observing that event with a backyard telescope, turn to Through the Eyepiece, page 51.



METEORS AT THE DARK OF THE MOON

The Lyrid meteor shower peaks on the night of April 21/22. The Moon is New that night, leaving the sky dark for meteor-watching. Lyrid meteors appear to radiate from a point near the border between Lyra and Hercules, some 10° southwest of Lyra's brightest star, sapphire-blue Vega. The radiant reaches its highest point in the sky shortly before dawn, the same time that Earth's nighttime hemisphere is plowing directly into the meteor stream. Thus the best time to watch this meteor shower is during the predawn hours of April 22.

The Lyrid meteor stream — the source of the particles that burn up in our atmosphere, creating the meteors — consists of tiny bits of debris orbiting the Sun. The debris was left behind by Comet Thatcher, which has been seen from Earth only once, in 1861, and isn't due back for nearly three centuries. Yet Comet Thatcher must be ancient because the Lyrids were first seen way back in 687 B.C. The 1981 shower was richer than usual, and in 1982 rates reached 75 meteors per hour and even higher for brief periods. Typical rates are closer to 15 meteors per hour but, with the Moon out of the way this year, you should give the Lyrids a try. Your best view will come from a rural location far removed from city lights.



STREAKS OF LIGHT SHOOT across the sky on the morning of April 22, when the Lyrid meteor shower peaks. Expect to see up to 15 meteors per hour radiating from Lyra, which lies nearly overhead just before twilight begins.

APRIL'S PLANETS

Mars remains prominent in the evening sky throughout April. It lies among the stars of Gemini, joining with that constellation's two brightest stars, Castor and Pollux, to form a trio of bright objects. Castor and Pollux are conspicuous because they are bright and near each other. Castor shines at magnitude 1.6 and Pollux, which lies 5° to the southeast, shines at magnitude 1.1. Mars is slightly brighter than those two, glowing at magnitude 0.8, and sports a distinct, ruddy hue. Though Mars passes 5° south of Pollux on April 14, the three remain near each other for several days around the middle of April. Look for them high in the southwest after darkness falls.

The giant planet **Jupiter** offers a noticeable contrast in color and brightness to Mars. It is much brighter than Mars at magnitude –2.4 and its color is creamy-white rather than reddish. Jupiter is visible nearly all night this month, a bold light in the faint constellation Virgo. It appears in the east when night begins and sets shortly before dawn.

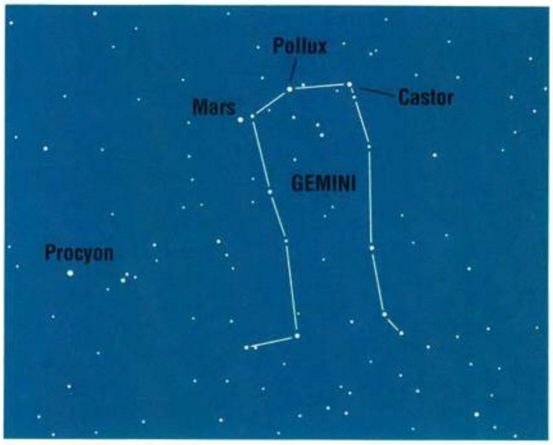
After Mars sets in the wee hours, Jupiter is the only bright planet you'll see until **Saturn** joins it in the predawn sky. The ringed planet rises just before morning twilight commences in early April and about an hour before twilight begins in late April. Saturn is not spectacularly bright — at magnitude 0.9 it shines about as bright as Mars — but is obvious among the background stars of Aquarius.

Mercury appears in the predawn sky throughout April, but the low angle of the ecliptic on spring mornings makes it difficult to see. The innermost planet reaches its greatest apparent distance from the Sun, or greatest elongation, on April 5. Mercury then lies 28° west of the Sun and shines at magnitude 0.3. Look for it around then or wait until midmonth, when the much brighter **Venus** lies 8° north of Mercury and serves as a convenient guide. The highlight for Venus this month comes on the morning of April 19, when the slender crescent Moon lies nearby. Next month Venus will climb higher and grow brighter in the predawn sky, becoming much easier to see.

THE STARRY SKY

At this time of year, the constellation Bootes ascends in the east after the Sun goes down. Some see Bootes as a kite-shaped figure. Others see

THE GEMINI "TRIPLETS" dominate the western sky after darkness falls around midmonth. Mars joins with Gemini's Castor and Pollux to form the impressive trio.



it as an ice cream cone, and still others claim it looks like an upside-down necktie. In this last case, Arcturus — the constellation's brightest star — marks the knot in the tie.

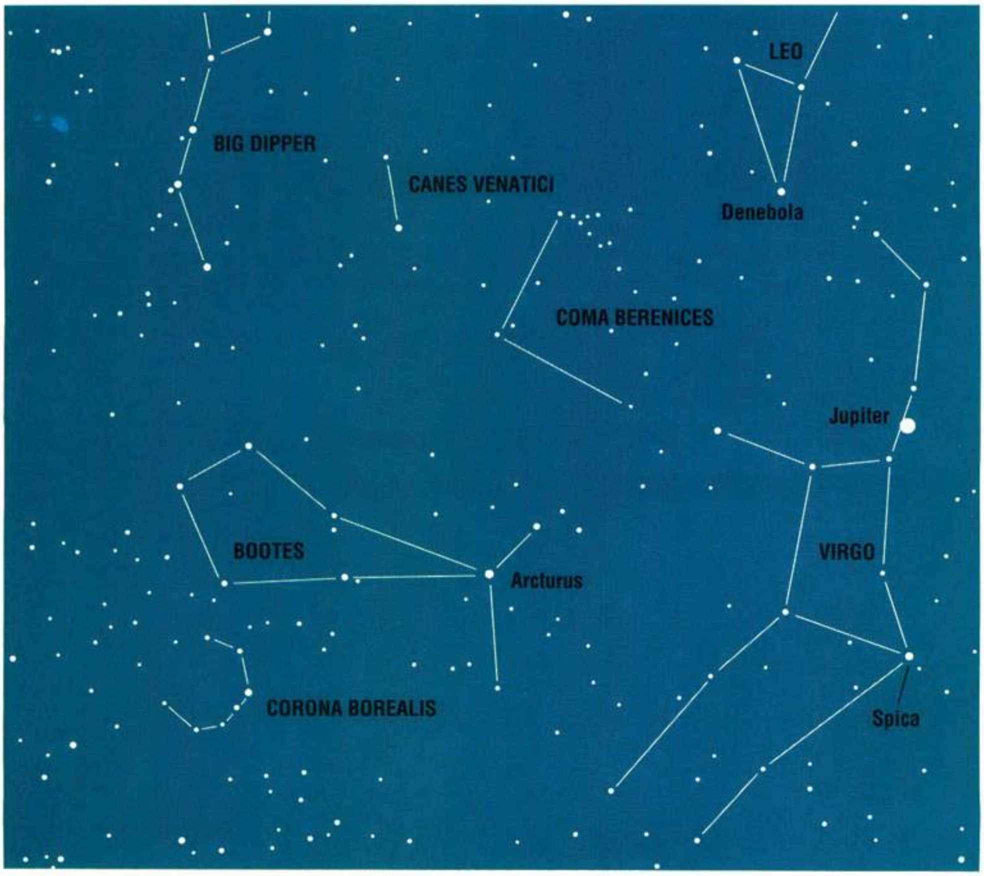
These are modern descriptions of a very old constellation. The name Bootes comes to us from at least 3,000 years ago. Bootes is the Herdsman, or Bear Driver. It is supposed to be herding nearby Ursa Major the Great Bear, which contains the well-known Big Dipper asterism. The early Egyptians regarded Ursa Major as malevolent, and Bootes was thought to be guarding her. But the Egyptians called the bear-guard a Hippopotamus.

In Greek mythology, Bootes is Icarius, who learned the art of growing grapes for wine-making from Dionysus, the god of wine. Icarius tried to share this art, but he was soon beaten to death by a group of shepherds who had become drunk and awakened with hangovers. In grief, Icarius' daughter — whose name was Erigone — hanged herself from a tree. Her dog was so grief-stricken that he jumped down a nearby well.

When Dionysus heard the news, he was outraged. He cast a spell over the maidens of Athens, causing them to hang themselves from trees. The frightened Athenians consulted an oracle who told them the girls' deaths would stop if the murderers of Icarius were found and punished. This was quickly done, and afterward the Athenians observed the death of Icarius each year during the grape harvest.

Meanwhile, Dionysus gave Icarius, his daughter, and her dog prominent places among the stars. Icarius became Bootes, Erigone became the constellation Virgo, and the Dog became the Dog Star, Sirius in the constellation Canis Major.

FOLLOW THE ARC TO ARCTURUS and its kite-shaped constellation Bootes on any spring evening. First find the Big Dipper high in the northeast and then extend its handle about 30° until you come to brilliant yellow-orange Arcturus.



Arcturus is Bootes' brightest star and the fourth brightest star in the entire sky. It is probably best known from the phrase "follow the arc to Arcturus and drive a spike to Spica." If you extend the handle of the Big Dipper about 30° to the south, you'll come to Arcturus. Extend the line farther and you'll come to the star Spica in Virgo.

To the naked eye, Arcturus appears yellow-orange and shines at magnitude –0.04. Most stars are like our Sun in that they lie in the disk of the Galaxy. But Arcturus belongs to the Milky Way's halo, a more or less spherical group of stars centered on the Galaxy's center. Right now Arcturus lies approximately 35 light-years from Earth, but it is cutting perpendicularly through the disk of the Galaxy. It became visible to the naked eye only some 500,000 years ago and will pass out of view in another half million years. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. It now can be heard on over 200 radio stations.

Through the Eyepiece *by Rick Shaffer*

A DAYTIME OCCULTATION OF VENUS

For observers in much of North America, the Moon passes directly in front of the planet Venus during daylight hours on April 19. Because this occultation occurs during the day, you won't be able to see it with your naked eye. But if you take binoculars or a small telescope to work or school, you should get a great view of this rare spectacle — the first occultation of Venus seen from much of North America in six years.

You'll be able to see the occultation if you live north of a line that runs from Miami, Florida, southwest through the Yucatan Peninsula. South of this line, the Moon passes north of Venus. In Miami itself, the southern limb of the Moon just grazes Venus at 12:40 p.m. Eastern Daylight Time.

The northern limit of the occultation path runs along a line that passes just north of Calgary, Alberta, and just south of Portland, Oregon. North of this line, the Moon passes south of Venus. The Moon occults Venus for the longest duration along the central path, which extends from southern Baja California up through El Paso, Texas, and Chicago, Illinois. In Chicago, the occultation begins at 11:02 a.m. and ends at 12:27 p.m. Central Daylight Time.

The most important consideration for viewing this daytime event is to protect your eyes and those of anyone who may be observing with you. Never point binoculars or an unfiltered telescope at the Sun — you risk immediate and severe damage to your eyes, and possible blindness. Luckily the Moon and Venus lie a healthy 26° west of the Sun at the time of occultation, so there's no need to point your scope near the Sun. If you can't find the pair with your naked eye, measure the 26° by extending your closed fist to arm's length. The long axis of your closed fist subtends an angle of approximately 10°, so the Moon and Venus lie about 2½ times the width of your closed fist west of the Sun. Sweep that area with binoculars to locate the two.

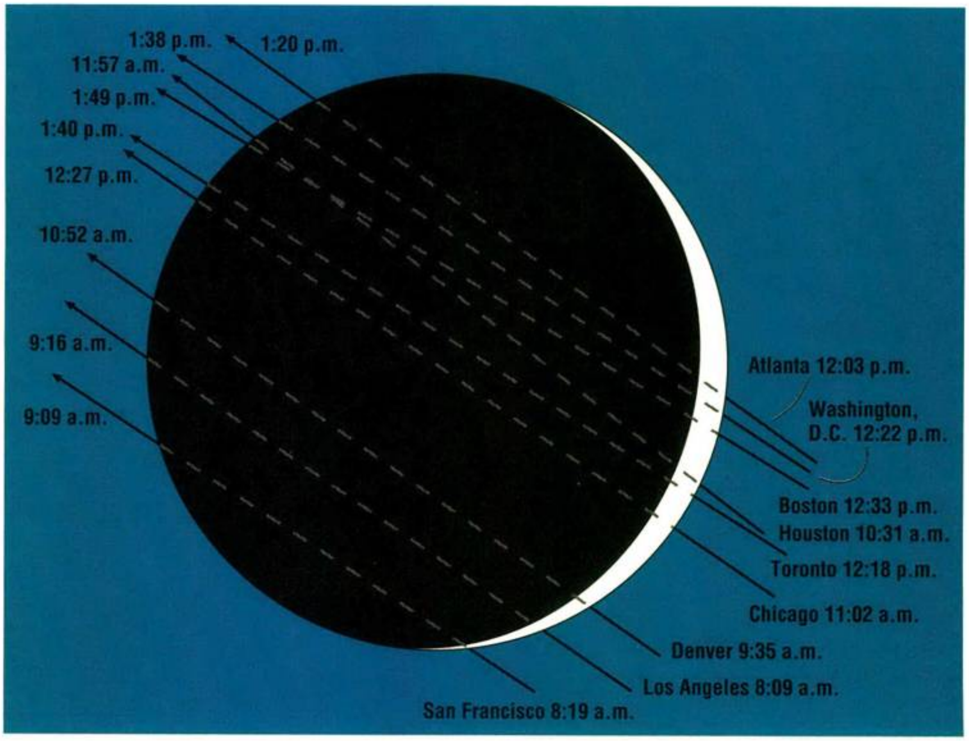
Because the Moon is a waning crescent, its illuminated limb passes in front of Venus. Normally the bright lunar limb overwhelms a soon-to-be-occulted object, but not this time: Venus is very bright, the 5-percent-lit Moon isn't very bright, and the daytime sky lowers the contrast between the two objects. All in all, you should get an excellent view as Venus disappears.

Sixty to ninety minutes later, for most observers, Venus reappears from behind the Moon's unilluminated limb. Unfortunately, that limb vanishes against the blue-sky background, so you'll have to watch the sky around the dark limb's location like a hawk to see Venus pop back into view.

As you view Venus near the lunar limb, it appears remarkably similar to the Moon, only smaller. Both show very slim crescents — the Moon is 5 percent lit at the time of the occultation and Venus 10 percent lit. The Moon, however, at 29.5' in diameter, dwarfs the 51"-diameter Venus. That's

Fred Espenak

THE MOON COVERS VENUS on April 19 for observers in most of North America. The time and appearance of the occultation vary with your location (below; south is shown at top and east at right), but everyone should see a scene like that captured during the July 17, 1974 event (above).



COORDINATES FOR COMET SCHAUMASSE

Date	R.A. (2000)	Dec.
April 1	8h03.9m	45°40'
April 6	8h32.1m	44°03'
April 11	8h58.5m	42°02'
April 16	9h22.9m	39°42'
April 21	9h45.1m	37°10'
April 26	10h05.4m	34°29'
May 1	10h23.9m	31°44'

Positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).

because Venus, even though it is physically 3.5 times larger than the Moon, lies 125 times farther away.

JUPITER JUST PAST OPPOSITION

Jupiter now lies in the evening sky, having reached opposition to the Sun on March 30. The giant planet rises just before sunset and transits the meridian shortly before local midnight.

Last month Jeff Kanipe detailed how to observe the Jovian disk, so this month I'll cover the meanderings of Jupiter's Galilean satellites. Fortunately, observing these four satellites — in order from Jupiter they are Io, Europa, Ganymede, and Callisto — doesn't require excellent seeing. In fact, you can see them with binoculars. (For a steady view, try bracing your elbows on the roof of a car, van, or pickup truck.) However, observing a transit of one of the satellites across the disk of Jupiter requires both good seeing and a telescope.

Transits are one of the four types of Galilean satellite phenomena you can observe with a backyard telescope. The others are shadow transits, eclipses, and occultations. In a transit, a satellite traverses Jupiter's disk. You'll need good seeing, a good telescope (usually 6 inches in aperture or larger), and a sharp eye to detect a satellite's disk against Jupiter. The satellite is easier to see when it lies in front of a dark belt or near Jupiter's limb. Of all the Galilean satellites, Ganymede is easiest to spot because it is the largest and relatively dark, while Europa is toughest because it is the smallest and brightest.

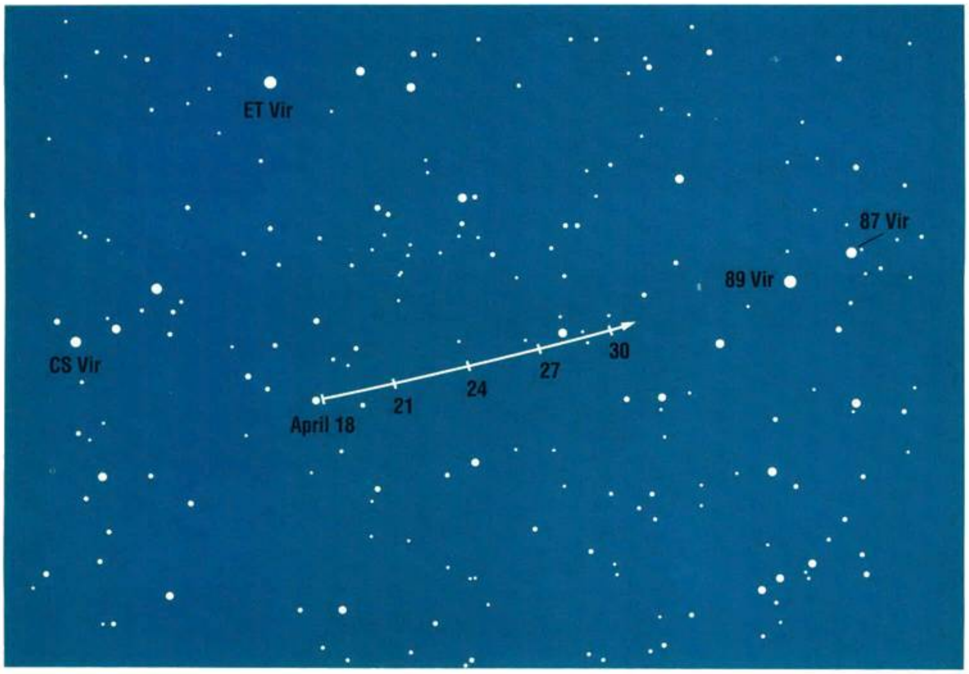
Shadow transits, in which a satellite's shadow crosses the Jovian disk, are much easier to see. The shadow is almost perfectly black, so there's a high contrast between it and Jupiter's cloudtops. In many cases, you can spot a satellite's shadow with a 3-inch scope in relatively poor seeing. Because Jupiter is now past opposition, the shadow follows the satellite across the disk.

When a Galilean satellite passes behind Jupiter, the planet can both eclipse and occult it. With opposition just past, the occultation comes first. In a telescope, you'll see a fully lit satellite disappear behind Jupiter's limb and then reappear from eclipse slightly off the opposite limb.

Io, because it has the shortest orbital period of the Galilean satellites, passes in front of and behind Jupiter most frequently, while Europa does so less often and Ganymede still less. Callisto passes neither in front of nor behind Jupiter's disk this year because it orbits far from Jupiter, and Earth lies slightly out of the plane of that orbit. We must content ourselves with watching it pass just above or just below the Jovian disk.

Use the table on the opposite page to plan your viewing of the Galilean satellite phenomena. It lists the best events visible from across most of North America during April. But be careful — you may become hooked on observing the dance of the Jovian moons.

ASTEROID AMPHITRITE CUTS through southern Virgo in late April, when it peaks at magnitude 9.4. Positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).



TELESCOPIC PLANETS

Because the ecliptic makes a small angle to the eastern horizon on spring mornings in the Northern Hemisphere, this April's morning apparition of **Mercury** is a poor one. Mercury reaches greatest elongation on the 5th, when it lies 28° west of the Sun, but that translates to an altitude of only 4° above the eastern horizon 30 minutes before sunrise. Look for Mercury around that date and again around April 16, when it passes 8° south of Venus. On that morning, Mercury appears 6.6" across and displays a 63-percent-lit disk.

Venus begins April in inferior conjunction and remains lost in the Sun's glare until the second week of the month. By the time it is occulted by the Moon on the 19th, the brilliant planet lies 26° west of the Sun and is an easy early morning object. You can observe it before sunrise on the 19th and then follow it right out to its appointment with the Moon.

Though **Mars** had a good opposition in January, its disk has now shrunk to 7" in apparent diameter and its magnitude dimmed to 0.8. On April 13, the Red Planet reaches quadrature, when it lies 90° east of the Sun in our sky. On that date it shows its most pronounced gibbous phase of the year, appearing 90 percent lit. However, only exquisite seeing will allow you to discern anything but the north polar cap and largest features on the Martian disk.

Saturn joins Venus in the early morning sky. On the 16th, when you search for Mercury south of Venus, Saturn is the pale yellow object 7° south of the crescent Moon. This month Saturn's disk measures 16" across and its rings span 36".

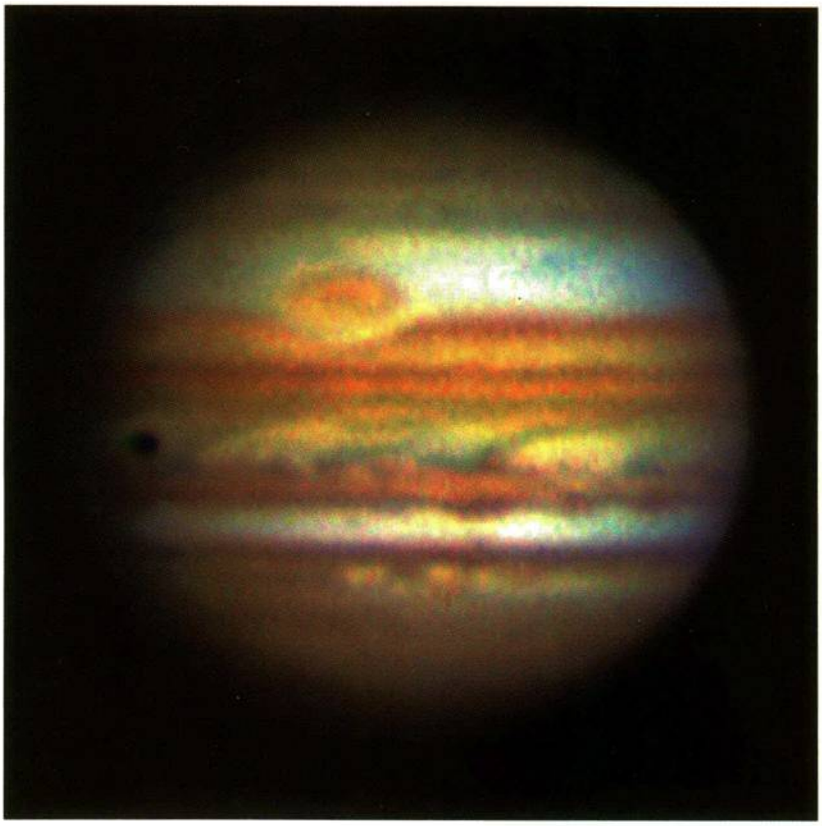
Uranus and **Neptune** reach heliocentric conjunction on April 21, which means they have the same longitude as seen from the Sun. This is a once-in-a-few-lifetimes occurrence — they were last in heliocentric conjunction in 1821, before the discovery of Neptune. They remain just over a degree apart throughout the year, and reach opposition on the same day, July 12.

COMETS AND ASTEROIDS IN THE EYEPIECE

Although it is now fading, **Comet Schaumasse** continues its journey through the northern sky this month. At midmonth you can find this 8th- to 9th-magnitude object in Lynx, about halfway between the head of Gemini and the bowl of the Big Dipper. Use the table on page 52 to plot the precise position of Comet Schaumasse on a star atlas.

This month's most-notable asteroid is **29 Amphitrite**, which reaches opposition on the night of April 24/25. You can find this 195-kilometer-diameter chunk of rock as a 9.4-magnitude point of light in southern Virgo. Use the map on the opposite page to locate this object. □

Rick Shaffer is an engineer and writer in the aerospace industry in Southern California.



Don Parker

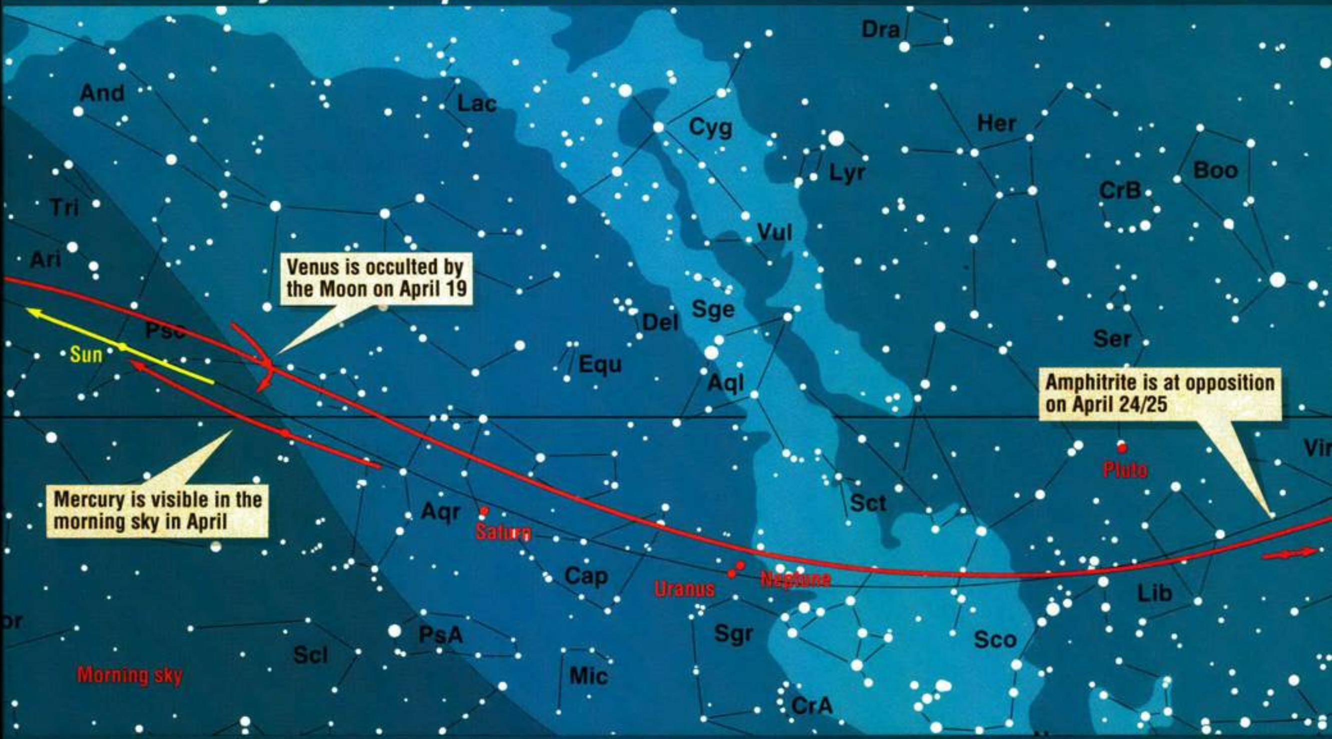
IO'S BLACK SHADOW appeared on Jupiter's disk on December 4, 1991 (above). You can see other phenomena of the Galilean satellites throughout April (below).

GALILEAN SATELLITE PHENOMENA

Date	Event	Time
	IO	
April 17	Transit begins	4h11m
	Shadow enters	4h36m
	Transit ends	6h23m
	Shadow leaves	6h48m
	EUROPA	
April 22	Transit begins	5h26m
	Shadow enters	6h29m
	Transit ends	7h52m
	Shadow leaves	8h58m
	GANYMEDE	
April 9	Transit begins	6h07m
	Shadow enters	6h58m
	Transit ends	8h43m
	Shadow leaves	9h47m

Times are given in universal time. Subtract 4 hours to convert to EDT, 5 hours for CDT, 6 hours for MDT, and 7 hours for PDT.

The Solar System April 1993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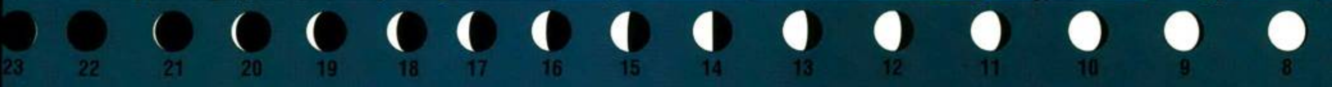
Morning sky

Venus is occulted by the Moon on April 19

Amphitrite is at opposition on April 24/25

Mercury is visible in the morning sky in April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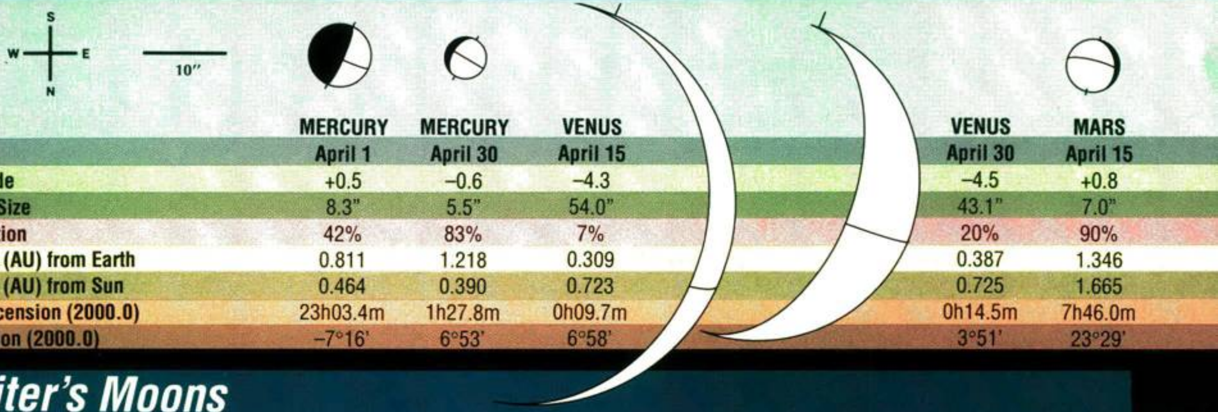
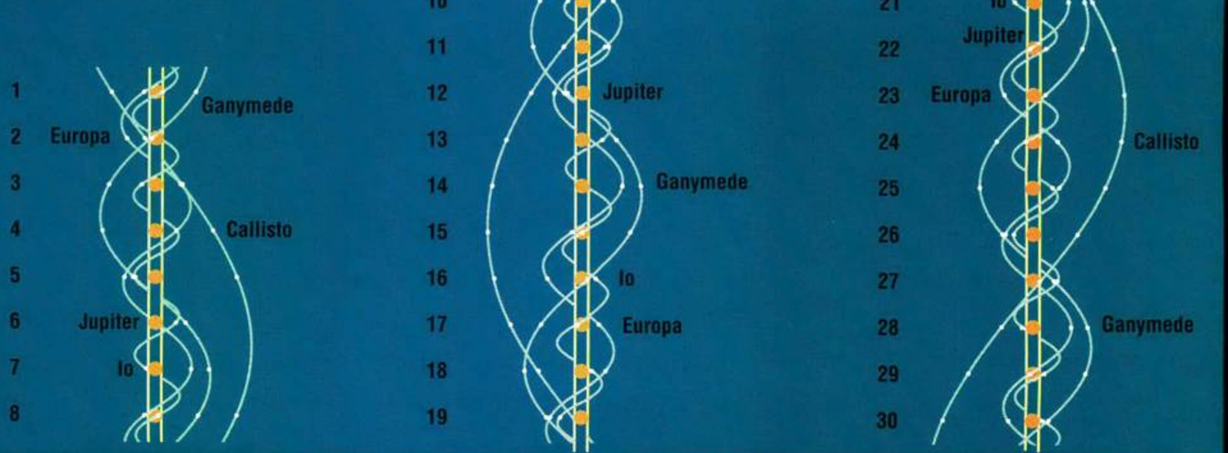
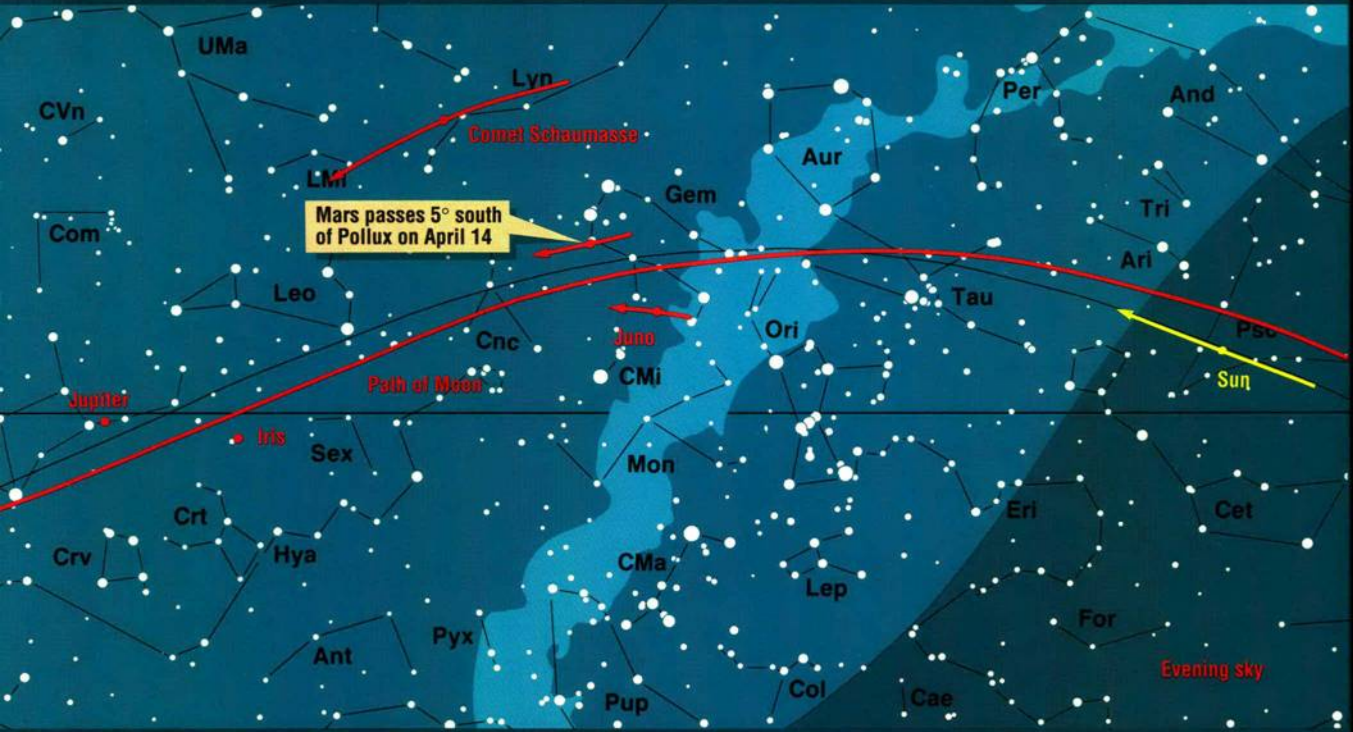


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	April 1	April 30	April 15	April 30	April 15
Magnitude	+0.5	–0.6	–4.3	–4.5	+0.8
Angular Size	8.3"	5.5"	54.0"	43.1"	7.0"
Illumination	42%	83%	7%	20%	90%
Distance (AU) from Earth	0.811	1.218	0.309	0.387	1.346
Distance (AU) from Sun	0.464	0.390	0.723	0.725	1.665
Right Ascension (2000.0)	23h03.4m	1h27.8m	0h09.7m	0h14.5m	7h46.0m
Declination (2000.0)	–7°16'	6°53'	6°58'	3°51'	23°29'

Jupiter's Moons

Dots display positions of Galilean satellites at 5 UT on date shown. South is at top to match the view in a telescope.

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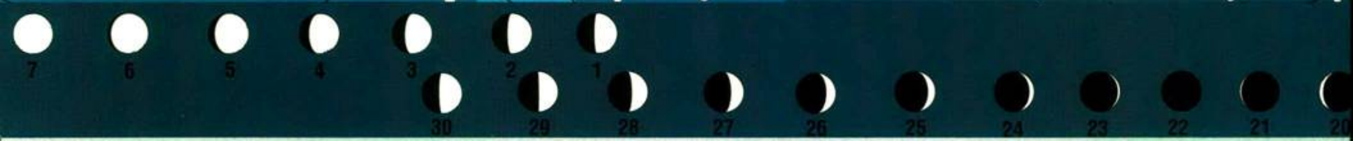
Evening sky

Mars passes 5° south of Pollux on April 14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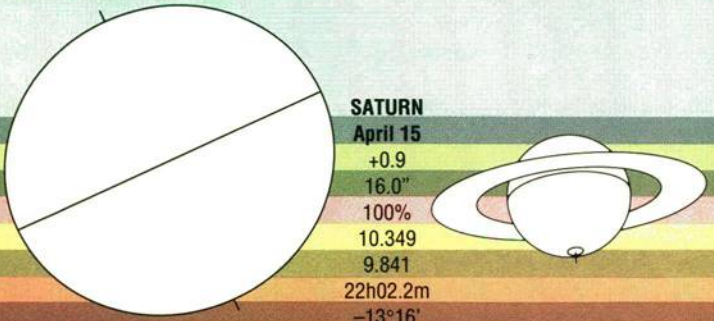
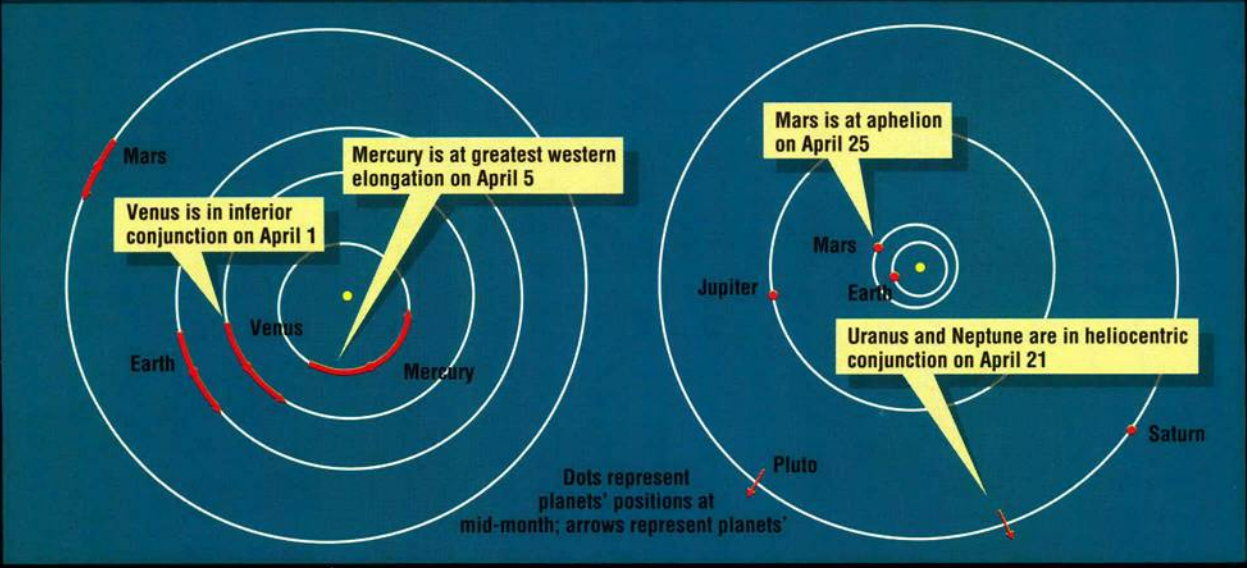


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
April 15	April 15	April 15	April 15	April 15
−2.4	+0.9	+5.7	+7.9	+13.7
43.9"	16.0"	3.6"	2.2"	0.1"
100%	100%	100%	100%	100%
4.487	10.349	19.513	30.101	28.884
5.453	9.841	19.590	30.186	29.730
12h31.7m	22h02.2m	19h36.3m	19h31.3m	15h44.8m
−1°42'	−13°16'	−22°03'	−21°06'	−4°37'

The Planets in Their Orbits


Mars
Venus
Earth
Mercury
Mars
Earth
Jupiter
Saturn
Pluto

Mercury is at greatest western elongation on April 5

Venus is in inferior conjunction on April 1

Mars is at aphelion on April 25

Uranus and Neptune are in heliocentric conjunction on April 21

Dots represent planets' positions at mid-month; arrows represent planets'

EXPLORING THE VIRGO CLUSTER OF GALAXIES

The closest big galaxy cluster in the universe offers a rich hunting ground for owners of small telescopes.

by Robert Garfinkle

No area of sky holds more galaxies than that included in the constellations Virgo and Coma Berenices. Although these springtime star groups are relatively dull to the naked eye, they lie far away from the plane of the Milky Way and thus allow us to see far into the universe unobstructed by the Milky Way's intervening dust. Virgo and Coma Berenices mark the direction not only of many bright galaxies visible in backyard telescopes, but indeed the brightest nearby group of galaxies, the Virgo Cluster.

On photographic plates, about 3,000 Virgo Cluster galaxies have been recorded in an area of sky bounded by 12h and 13h right ascension and +10° and +30° declination. Backyard observers can see between 250 and 500 of these galaxies in small telescopes. All of the Virgo and Coma Berenices galaxies appear relatively faint — no Andromeda Galaxies, giant spirals like M33 and M51, or Magellanic Clouds exist here. Because of this, you should hunt for the Virgo galaxies on a dark, moonless night from a clear site with good transparency. Use a low-power eyepiece that yields 30x to 50x when locating the galaxies and then switch to higher powers to get the best view of individual galaxies within the cluster.

A giant, sweeping arc beginning in Coma Berenices and following through Virgo shows you the best galaxies in the cluster. To galaxy hop in the area, consult a relatively detailed star atlas like *Sky Atlas 2000.0* by Wil Tirion. Coma Berenices contains few bright guide stars, so let's start at golden Arcturus in the constellation Bootes. From Arcturus, follow a trail of stars west to reach the 4th-magnitude double star Alpha Comae Berenices. This star is slightly east of the midpoint between Arcturus and Denebola (Beta Leonis).

Some 5½° northwest of Alpha lies the 5th-magnitude double 35 Comae Berenices. Sweep ¾° east-northeast of this star and you'll spot the **Blackeye Galaxy** (M64, NGC 4826). Johann Bode discovered this Sb-type spiral galaxy in 1779. Charles Messier first recorded observing the Blackeye on March 1, 1780. The core of this oval-shaped galaxy is bright enough to see in a 2-inch telescope. A thick dust lane obscures the northeastern side of the core, giving the galaxy its nickname, and this feature shows up nicely in a 6-inch telescope at high power. Larger scopes show a mottled appearance around the galaxy's core and a very faint halo of light surrounding the bright center.

Aim your telescope just 4° north of M64 to see another bright spiral, **NGC 4725**. At magnitude 9.2, this face-on barred spiral is visible as a smudge in

NGC 4567 and NGC 4568

Mags. 11.3 and 10.8

Sizes 3' by 2' and 5' by 2'

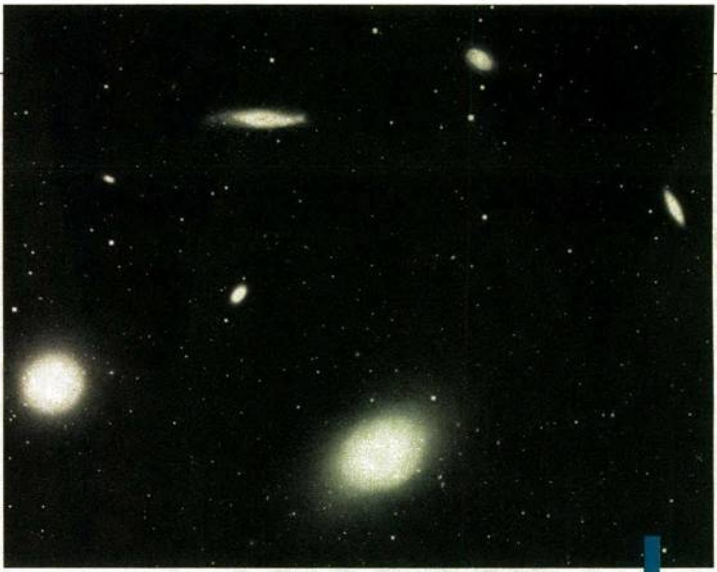
by Martin C. Germano

Heart of the Virgo Cluster

by Kim Zussman

THE HEART OF THE VIRGO CLUSTER

by Richard Jakiel



M84 and M86 area

Field approximately 1/2°

Kitt Peak National Observatory photo

Galaxies usually exist in clusters but they are rarely clustered to the extent they are in the heart of the Virgo Cluster. Here you could spend hours with a high-power eyepiece in your scope scanning the region and finding galaxy after galaxy. The opportunity to see a great variety of galaxies shouldn't be passed up this spring.

Two giant ellipticals, M84 and M86, are the dominant members of a 16-galaxy aggregation that defines this core region. All of these galaxies are located in an area of less than one square degree. These systems are only 17' apart on a nearly east-west line. **M84** (NGC 4374) is located in the western part of the core, an immense spheroid over 250,000 light-years in diameter. Although for many years it has been classified as an E1 elliptical, long-exposure photos show faint traces of spiral structure, suggesting that M84 may be a face-on lenticular galaxy. This galaxy is much more massive than our own Milky Way, tipping the scales at over 5 trillion solar masses. In a small telescope, M84 is bright and slightly oval, with a large, dense core. In a 20-inch scope, the overall view is only moderately different. At 175x, M84 appears as a fairly large, very bright galaxy of high surface brightness. It is slightly oval, with a round core surrounding an intense nucleus. Overall, M84 has a slightly granular texture.

Nearly 10' due south is **IC 3303**, a tiny elliptical galaxy similar to M32. IC 3303 has perhaps 1/50,000 of the mass of its huge neighbor. In a 20-inch scope, IC 3303 is a tiny, diffuse patch dimly glowing at 15th magnitude. The direction of elongation is nearly east-west, with a 2:1 length/width ratio. Nearby is the small elliptical galaxy **NGC 4387**. In a 20-inch scope at 175x, it appears as a small nebulosity with a bright core.

About 1/2° southeast of M84 you'll find **NGC 4413**, a small, diffuse spiral galaxy. The galaxy appears oval, with a faint envelope surrounding a weak central condensation. The texture is somewhat mottled, while overall surface brightness is rather low. Moving southeast from NGC 4413, you'll spot a collection of faint spirals and dwarf systems. **IC 3363**, a dwarf elliptical, lies 7' east-southeast of NGC 4413. In a 20-inch scope at 175x, the object is a small, faint oval with a slight central condensation. I estimate its size at 20" by 15" and brightness at about magnitude 15.5. The elliptical **IC 3349** makes a right triangle with IC 3363 and NGC 4413. Backyard scopes show IC 3349 as a tiny patch of nebulosity oriented north-south with a stellar core. IC 3349 spans 20" by 10" and glows at only 15.5 magnitude, making it a difficult object for even large scopes.

In the far southeast corner of the Virgo core is a trio of small spiral galaxies. The brightest of these, **NGC 4440**, is visible in moderate-sized scopes as a nearly round, bright object with an oval core. Moving a little over 2' northwest of this galaxy brings you to **NGC 4436**, the faintest of the group, a dim patch elongated northwest-southeast. It has a bright core embedded in a diffuse outer halo. **NGC 4431** lies in the same high power field, about 7' west of NGC 4440. It is visible as a diffuse patch. The elongation ratio is about 2:1 in a north-south direction.

Heading back north again, we find the brightest galaxy of the region: **M86** (NGC 4406). A giant elliptical galaxy similar to nearby M87, M86 may be a foreground object. Easy to see in small scopes, M86 is an impressive object in a large aperture. Slightly brighter than M84, it is noticeably larger and is slightly oval in shape. The elongation is oriented northwest-southeast, in a 4:3 length/width ratio. The core area is dense with a small, intense nucleus. This is embedded in a large, diffuse halo. Like many bright ellipticals of the region, it has a somewhat granular texture similar to an unresolved globular cluster.

The last two galaxies in Virgo's core both appear to be anemic spirals; the dust and gas in these objects has been stripped away by interaction with other galaxies. Just about 10' to the north lies an edge-on galaxy, **NGC 4402**. Some 15' south of M86 is another edge-on spiral, **NGC 4388**. In the telescope, NGC 4402 is a fairly large, cigar-shaped object having a lower surface brightness than NGC 4388. In a 20-inch scope it appears as an elongated object oriented east-west. The core is weakly developed, and the surface is mottled with low contrast light and dark areas. NGC 4388 appears similar. The 20-inch scope reveals a mottled surface of relatively high surface brightness. NGC 4388 is also surrounded by a large, diffuse envelope oriented northwest-southeast that is elongated about 2:1. The core is quite dense, with a faint stellar nucleus.

binoculars and is really impressive in a 6-inch scope. A sprinkling of 8th- to 12th-magnitude foreground stars lies scattered across the field. Just northeast of NGC 4725 you may see the 12th-magnitude peculiar galaxy **NGC 4747**. Because we see this galaxy almost edge-on, it lacks a spiral shape, but in photographs a prominent bar is visible.

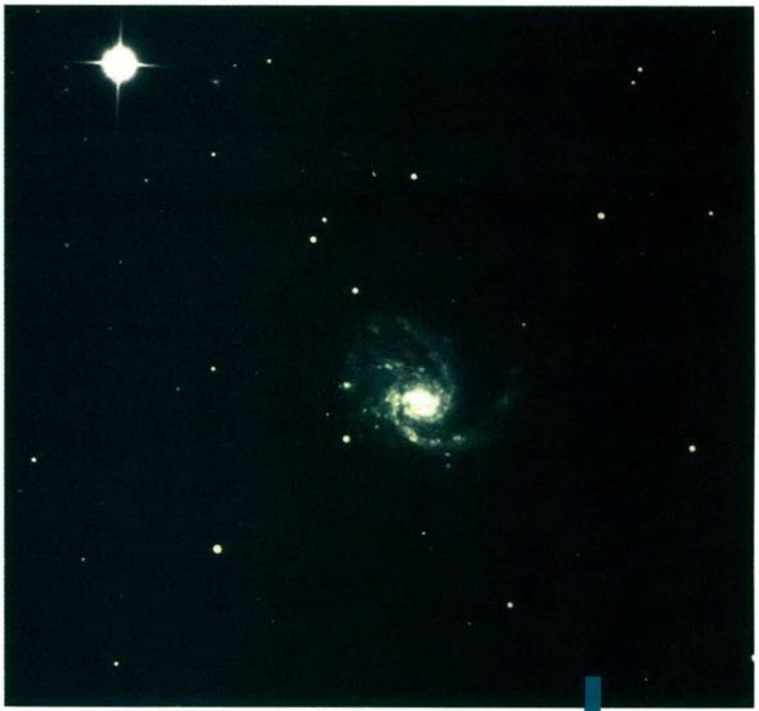
Considered by some to be the most beautiful edge-on galaxy in the sky, **NGC 4565** lies 3 1/2° west of NGC 4725, about 2° east of 17 Comae Berenices. At magnitude 9.6, this streak of light — which measures 16' by 3' — is one of the few galaxies that appear impressive in binoculars. In telescopes a prominent dust lane bisecting the core is visible. A 6-inch scope shows this galaxy as a silvery needle of light stretching halfway across a low-power field. A 10-inch scope nicely reveals the central bulge around the nucleus of this object and the razor-thin dust lane extending across half the galaxy's length. Larger backyard scopes show even more detail in NGC 4565, including a bright knot of light at the galaxy's center.

To locate several galaxies near the Coma-Virgo border, return to Denebola. Move 6° east to the white, 5th-magnitude star 6 Comae Berenices. The barred spiral galaxy **M98** (NGC 4192) lies west of this star in the same low-power field. This faintly glowing edge-on galaxy was first seen by Pierre Mechain on March 15, 1781. Although it is not a member of the Virgo Cluster — it lies about half the distance from us — this object is an observational treat. Spanning 10' by 3' and glowing at magnitude 10.1, M98 can be seen in telescopes as small as 2 inches in aperture. The galaxy's disk is bright, with a bright center, and in large scopes it appears to be slightly kinked, or twisted. A faint halo of milky light surrounds the bright disk component of this galaxy, although a 10-inch or 12-inch scope is needed to reveal it.

You'll find another bright galaxy just 1° southeast of 6 Comae Berenices — **M99** (NGC 4254). Unlike M98's near edge-on orientation, M99 is positioned so we see it nearly face-on. Because of this, the galaxy's spiral arms are relatively easy to see as they wind outward from a bright central glow. M99 measures 5' across and glows at magnitude 9.8, making it visible in the smallest telescopes. Mechain found this object on the same night as he found M98.

Moving east-northeast of 6 Comae Berenices will bring you to a distinctive pair of 5th-magnitude stars. These point to the large Sc-type spiral **M100** (NGC 4321). Mechain discovered this galaxy, one of the largest and brightest spirals in the Virgo Cluster, on March 15, 1781. M100 glows at magnitude 9.4 and measures 7' by 6'. The galaxy's center stands out in any scope. A 4-inch instrument shows the large oval glow that surrounds the center. A good 8-inch scope on a dark night shows the subtle spiral structure of M100's arms, which appear to unwind in a clockwise direction around the nucleus. In a low-power, wide-field eyepiece, you may be able to include the elongated, 12th-magnitude galaxy **NGC 4312** south of M100. Two 13th-magnitude spiral galaxies, **NGC 4322** and **NGC 4328**, are less than 15' east and northeast of M100. You will need dark skies, good seeing conditions, and a large scope to observe these objects.

About 1 3/4° north-northwest of M100 you'll spot the 5th-magnitude yellow double star 11 Comae Berenices.



M99

Mag. 9.8

Size 5'

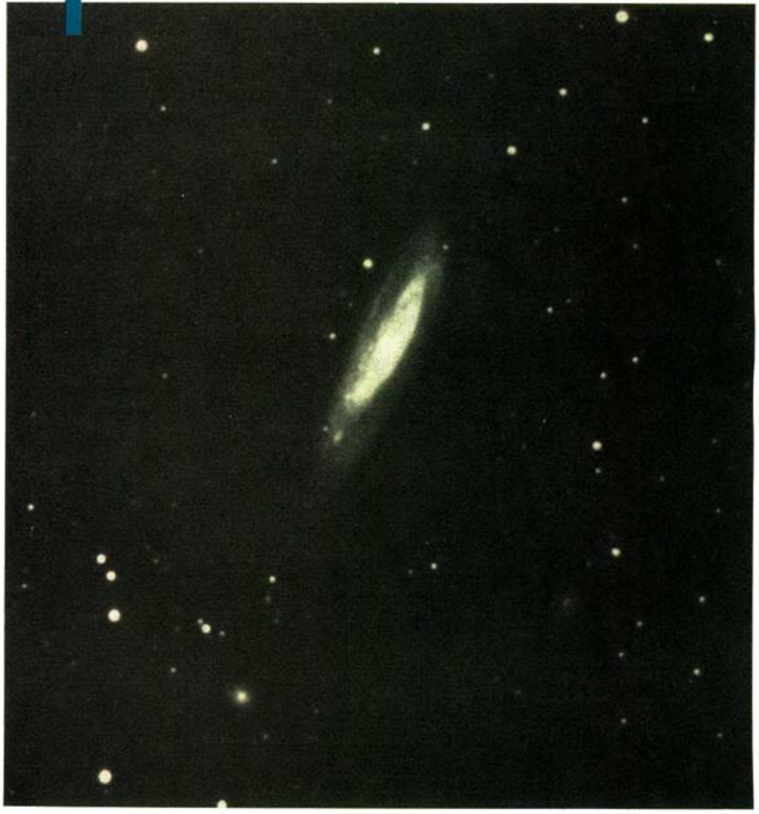
by Kim Zussman

M98

Mag. 10.1

Size 10' by 3'

by Martin C. Germano



One and one-half degrees northeast of this star lies the peculiar galaxy **M85** (NGC 4382). This small galaxy glows at 9th magnitude and spans 7' by 5', making it visible in small scopes. Mechain discovered this galaxy on March 4, 1781. Messier confirmed the discovery two weeks later. An elliptical galaxy, M85 lacks the kind of detail a typical spiral shows. Instead, M85 is a fuzzy oval glow that displays a bright, central condensation. East of M85, in the same low-power field, is the barred-spiral galaxy **NGC 4394**. This 11th-magnitude galaxy appears like a circular smudge of light.

Having seen M85, you may wish to return to 6 Comae Berenices and then to M99. Now you can test a simple method for finding **M88** (NGC 4501) if you have an equatorially mounted telescope. M88 lies at about the same declination as M99, so center M99 in your eyepiece, turn off your motor drive, and wait about 14 minutes for M88 to drift into your view. M88 is an Sc-type spiral and appears elongated as we are looking at it slightly face-on. Its core appears almost stellar. M88 glows at magnitude 9.5 and covers 7' by 4' of sky, so it appears bright even in a small telescope. M88's center is highly condensed, and observers with 6-inch or larger scopes can see an extended halo of gray light around this central region. You may spot two bright stars on the galaxy's southern end.

Move your scope less than 1° east of M88 and you'll find the 10th-magnitude barred spiral **NGC 4548**. This

M88

Mag. 9.5

Size 7' by 4'

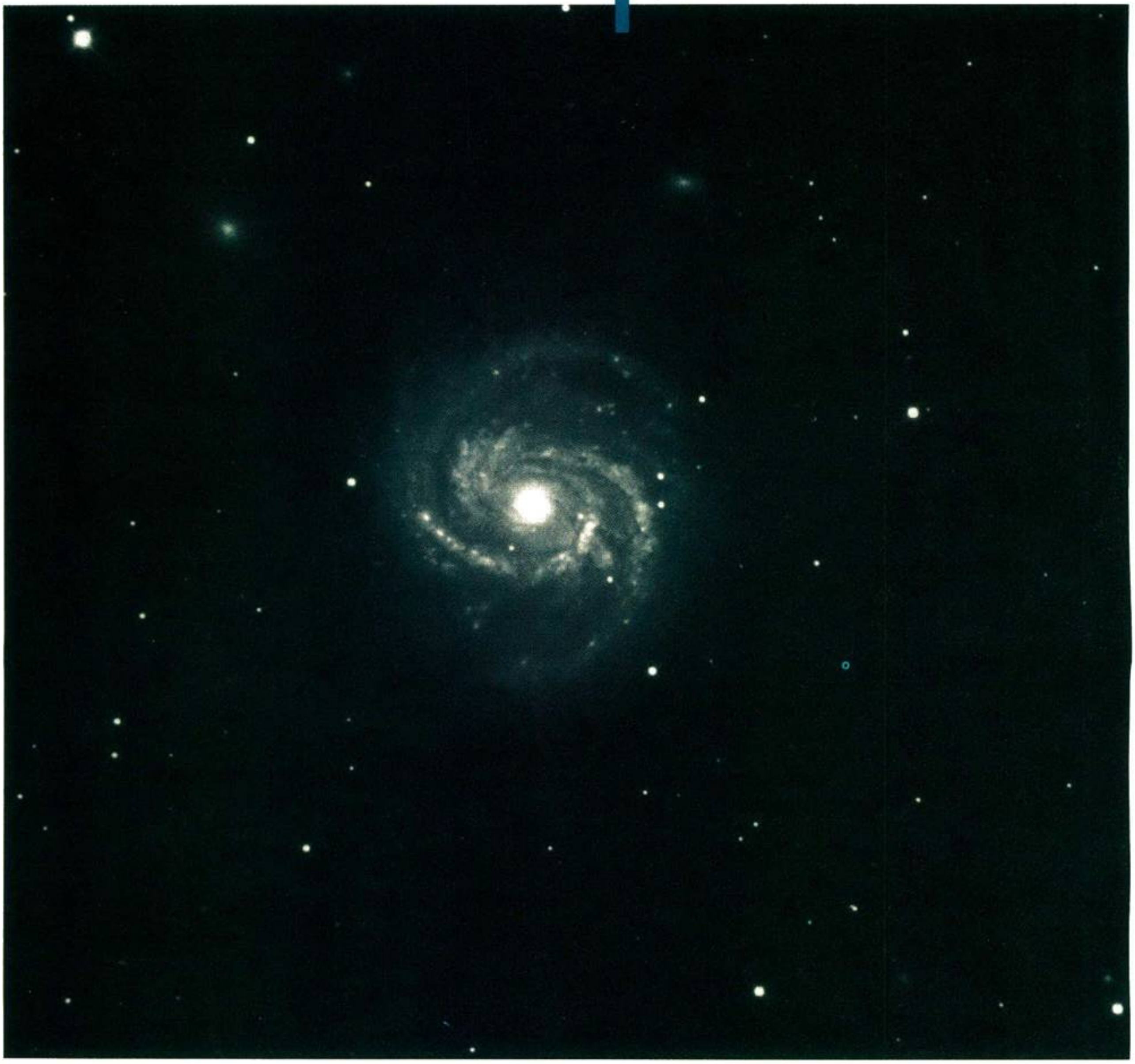
by Kim Zussman

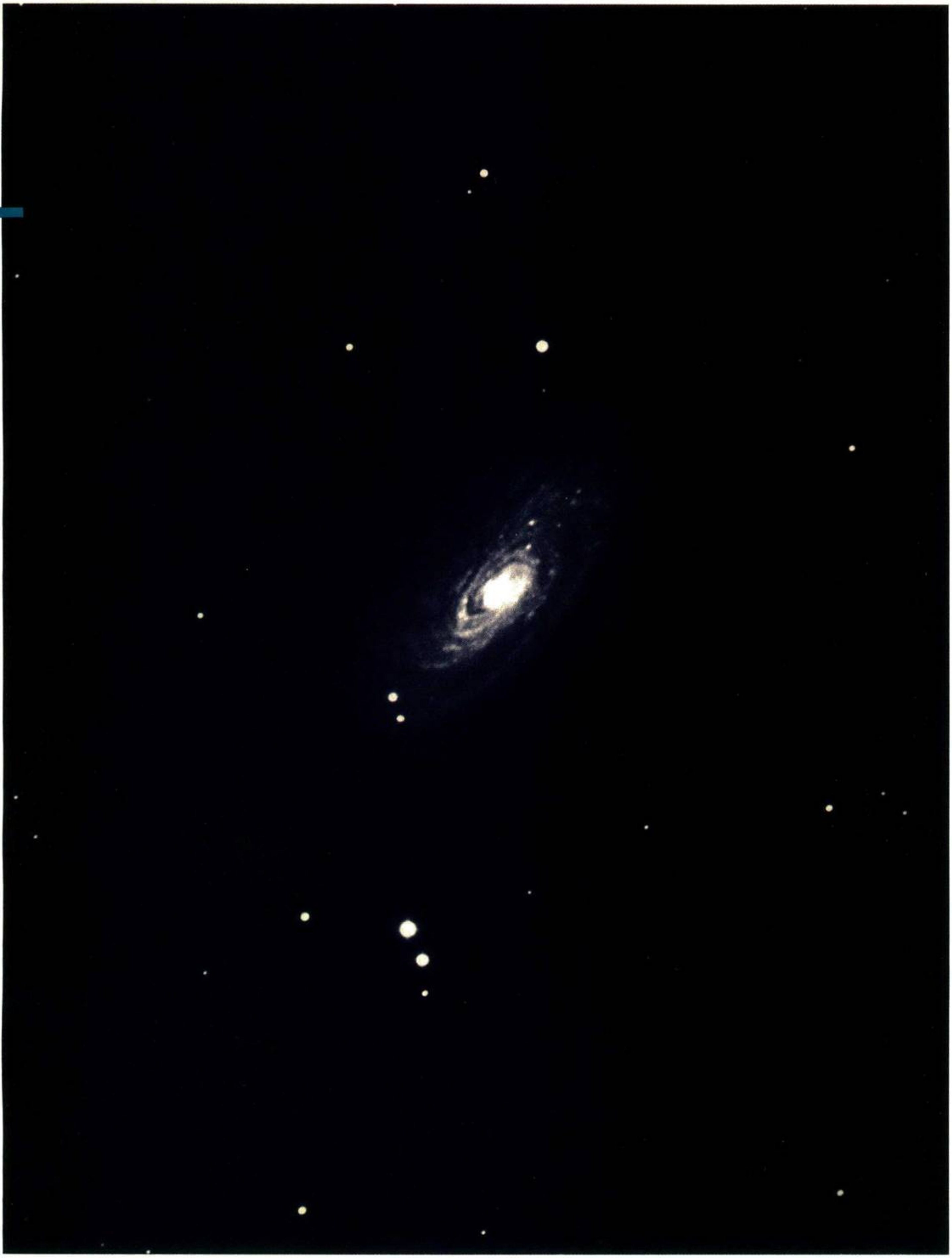
M100

Mag. 9.4

Size 7' by 6'

by Kim Zussman





The Blackeye Galaxy (M64)
Mag. 8.5
Size 9' by 5'
by Kim Zussman

NGC 4565
Mag. 9.6
Size 16' by 3'
by Joe Liddell

galaxy has hazy, ghostlike spiral arms extending away from a bright center. Half a degree southeast of NGC 4548 lies the 11th-magnitude spiral **NGC 4571**. This galaxy appears round and is evenly illuminated across its 4' diameter.

To locate the galaxies in the central portion of the cluster, find the 3rd-magnitude yellow-white star Vindemiatrix (Epsilon Virginis). From Vindemiatrix, star-hop about 4° northwest to the double star 34 Virginis, then 1° southwest to the giant elliptical galaxy **M60** (NGC 4649). On April 11, 1779, Johann Koehler discovered M60 when the comet that now bears his name passed near the galaxy. Messier made an independent discovery on April 15, 1779. In small scopes M60 appears like a large, oval glow of about 9th magnitude. A halo of faint nebulosity seems to surround the much brighter core. In a wide-field, low-power eyepiece, you may also be able to spot the elliptical galaxy **M59** (NGC 4621) northwest of M60. At magnitude 9.8, M59 appears oval with a bright core.

Move about 1° northwest of M59 and you'll find the barred spiral galaxy **M58** (NGC 4579). Messier first saw this magnitude 9.8 object on April 15, 1779. M58 is considered to be almost a twin to our galaxy in size and mass. It appears elongated with low surface brightness. An unusual galaxy pair lies about 30' southwest of M58. The "Siamese Twins" are Sc-type galaxies **NGC 4567** and **NGC 4568**. The latter is slightly brighter at magnitude 10.8 and appears larger than NGC 4567. Look for the magnitude 9.8 elliptical galaxy **M89** (NGC 4552) about 1$^1/_2$° north-northwest of the Siamese Twins. Messier found this round galaxy on March 18, 1781. This galaxy appears as a glowing patch with a bright center.

Aim your scope about $^3/_4$° northeast to find the beautiful 9th-magnitude spiral **M90** (NGC 4569) and its irregular companion **IC 3583**. At magnitude 13.6, IC 3583 is a challenging faint object for small scopes. Because we see it at about a 30° angle from face on, M90 appears as an elongated oval. The core appears bright in a large scope, and dust lanes are visible on nights of exceptional transparency. The galaxy is about 80,000 light-years in diameter and contains the mass of 80 billion Suns.

One and one-half degrees southwest of M90 you'll find the giant elliptical galaxy **M87** (NGC 4486). This enormous sphere of stars is one of the largest elliptical galaxies known. Messier discovered M87 on March 18, 1781, and noted it with his usual comment of "nebula without star, in Virgo." At high power a small telescope shows a fuzzy ball of light glowing at magnitude 8.6 and measuring 7' across. Although little detail is visible in backyard scopes, realizing the nature of M87 makes it a fascinating object.

M87 contains 800 billion solar masses. In addition to its great light output, M87 is a strong source of radio energy, a distinction that gave it the designations Virgo A and 3C 274. The giant galaxy contains a system of more than 4,000 globular star clusters, far more than any other known. Astronomers have recorded great detail in a jet of material being shot from this galaxy's center. Last year astronomers using the Hubble Space Telescope imaged this jet and provided evidence to back the suspicion that M87's center harbors a powerful black hole.

One degree northwest of M87 lie the bright ellipticals **M84** (NGC 4374) and **M86** (NGC 4406). Glowing at magnitude 9.2, M86 appears nearly circular, with a slight brightening in the middle. M84 appears quite similar to M86, but it is slightly dimmer and smaller.

You've now explored in detail the Virgo Cluster of galaxies, the great cloud of island universes in our part of the universe. What did you think of the forms and variety of galaxies you observed? Did the range of brightnesses and features surprise you? A great test of observational skills goes like this: Make some notes about your favorite objects in the Virgo Cluster. In a year or two, come back to this great galaxy warehouse and observe the same objects, making extensive notes about their appearances. Compare the two sets of notes. You may be surprised at the results. The Virgo Cluster is not only one of the observational wonders of the universe, it is also a great classroom that can teach us a great deal about how to see deep-sky objects. ☐

Robert Garfinkle's last article was "Exploring the Wonders of Scutum," in the July 1992 issue. He is the author of Star-Hopping, *to be published by Cambridge University Press.*

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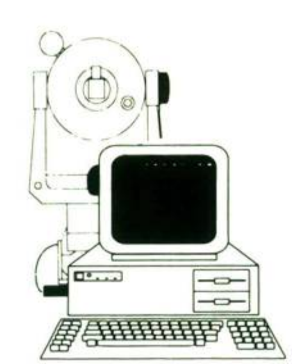

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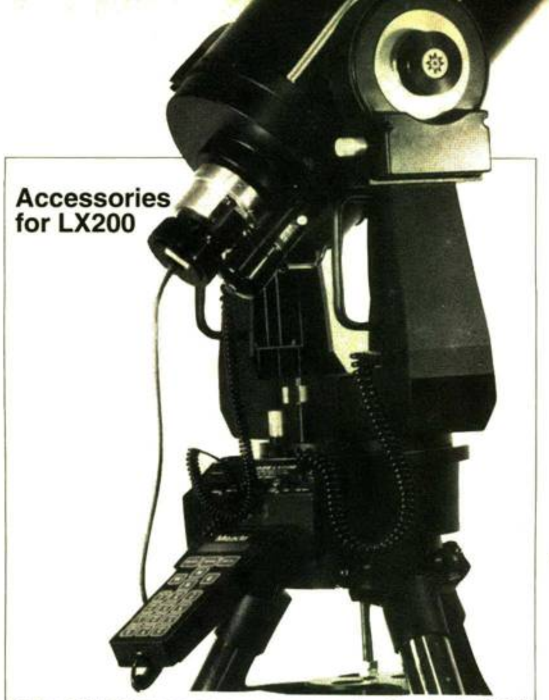

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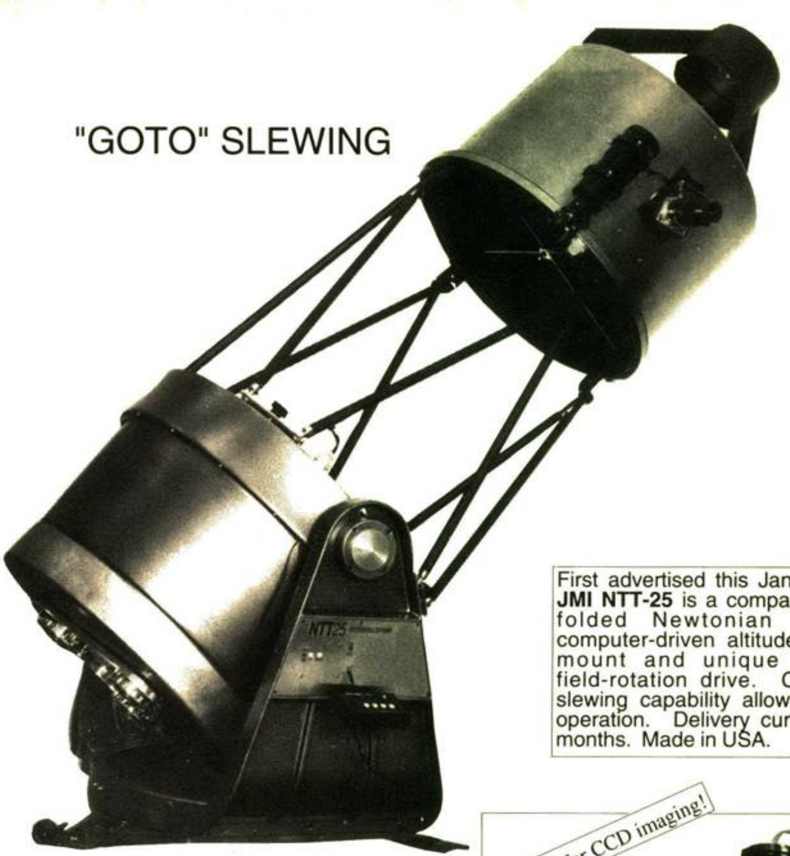

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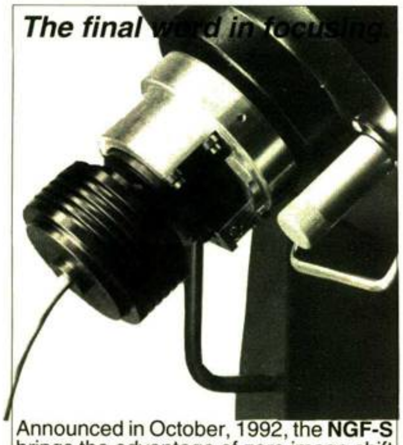
While demonstrating the **NTT-25** at the Ultimate Star Party, Mark Bridges and a fellow director from McDonald Observatory requested a look at the Saturn Nebula. "Sure." I said, "But I need a catalog number." "We don't know, but Tom has his 'scope on it." was the reply. "No problem!" I returned, remembering the **NGC-MAX**'s Identify Mode. I pointed the 25" in the general direction of the other telescope and asked the **NGC-MAX** to identify the nearest planetary nebula. Within three seconds it had identified the Saturn Nebula. I then used the Guide Mode to point the telescope to the correct position and there it was! "That took you all of 20 seconds!" exclaimed Bridges.

As for the **NTT-25**, an **NGT-18** owner flew all the way from Australia just to see the telescope in operation. He was not disappointed, in fact, he reported "JMI is so far ahead of everyone else in the USA, it isn't even funny!". Needless to say, all present were very impressed.



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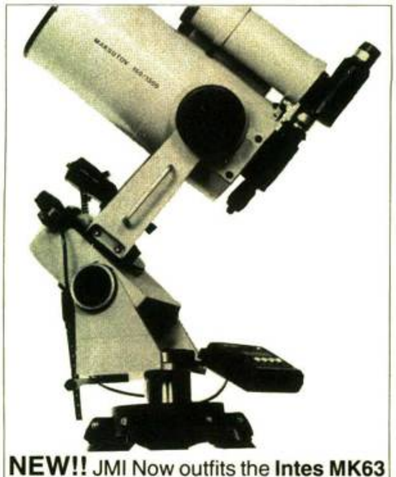

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S93D2

MARE NECTARIS

Use your telescope to take a walk around one of the finest ring basins on the Moon.

by Robert Burnham

About five days after New Moon, a giant lunar ruin comes into view. That's when the morning Sun rises over Mare Nectaris, the Sea of Nectar. Lying just south of the Moon's equator, Mare Nectaris is the dark patch below the Man in the Moon's left eye. It's a remarkable place every telescope owner should spend a few evenings exploring. No other lunar "sea" visible from Earth shows you so clearly the scars of its origin.

Mare Nectaris is a thin sheet of congealed lava about 350 kilometers across. However, it fills only the center of a much larger feature, the Nectaris impact basin, 860 km in diameter. Scientists think the Nectaris basin formed when a large asteroid slammed into the Moon 3.92 billion years ago. The hammerblow excavated a wide saucer-shaped depression and sent out shock waves and debris. Locally, rocks shattered and heaved skyward. Then they froze in place, leaving several uplifted rings of cliffs around the impact site.

Soon after, molten lava oozed out of the lunar interior and crept through the basin's low-lying areas. The lava pooled in a sheet 1 to 2 km thick. It softened, melted, and covered the twisted tangle of rocks. The lava destroyed many craters outright; others saw parts of their walls melted away. Eventually the lava cooled and hardened. Since then a handful of smaller impacts has pitted the surface at random.

Let's start our tour at the south end of the mare. Here lies the crater Fracastorius, 124 km in diameter. Its northern wall was nearly destroyed by the lava, showing that the crater formed within a sliver of lunar time — after the basin impact but before the lava floods. A high-power eyepiece will show that the floor of Fracastorius is marked by a few minute craterlets and a shallow rille (valley) running east-west.

Continuing clockwise around the shore of the mare you'll see another ruined crater, 53-km-wide Beaumont. From Beaumont a wrinkle ridge runs northward, while a similar set of ridges parallels the eastern shore. These may have formed as the lava sheet settled and buckled.

Now use medium power to pull back and view the general form of Mare Nectaris itself. The lava sheet has filled the lowest portion of the circular basin, up to the first "bathtub ring." The ring is actually a relic of the basin-making impact, thrown up by shock waves in the first few seconds after the asteroid struck. With a little practice you can spot two or three other concentric rings farther out. All, however, are broken or incomplete, and the parts of the rings that lie east of the mare have been wiped out by the lavas of Mare Fecunditatis.

The most outstanding section of basin rings is called Rupes Altai, or the Altai scarp. Under lunar morning light the scarp shows as a bright conspicuous line to the west and southwest of the mare, about one mare-diameter out. The scarp begins in the north, near where the lavas of Mare Tranquillitatis flow south through Sinus Asperitatis. Onward it goes, south and then bending east around the southern end of the mare. It appears to end at Piccolomini, a pretty, terraced crater 88 km across.

Southeast of Piccolomini lies Vallis Rheita, the Rheita valley, about 500 km long and 30 km wide. This is another birthmark of the Nectaris basin. Scientists believe it is a chain of secondary craters spawned when a string of debris flung out by the basin impact struck the ground with explosive force. Take time to explore the valley's twisting length, and imagine yourself cruising it in a spaceship.

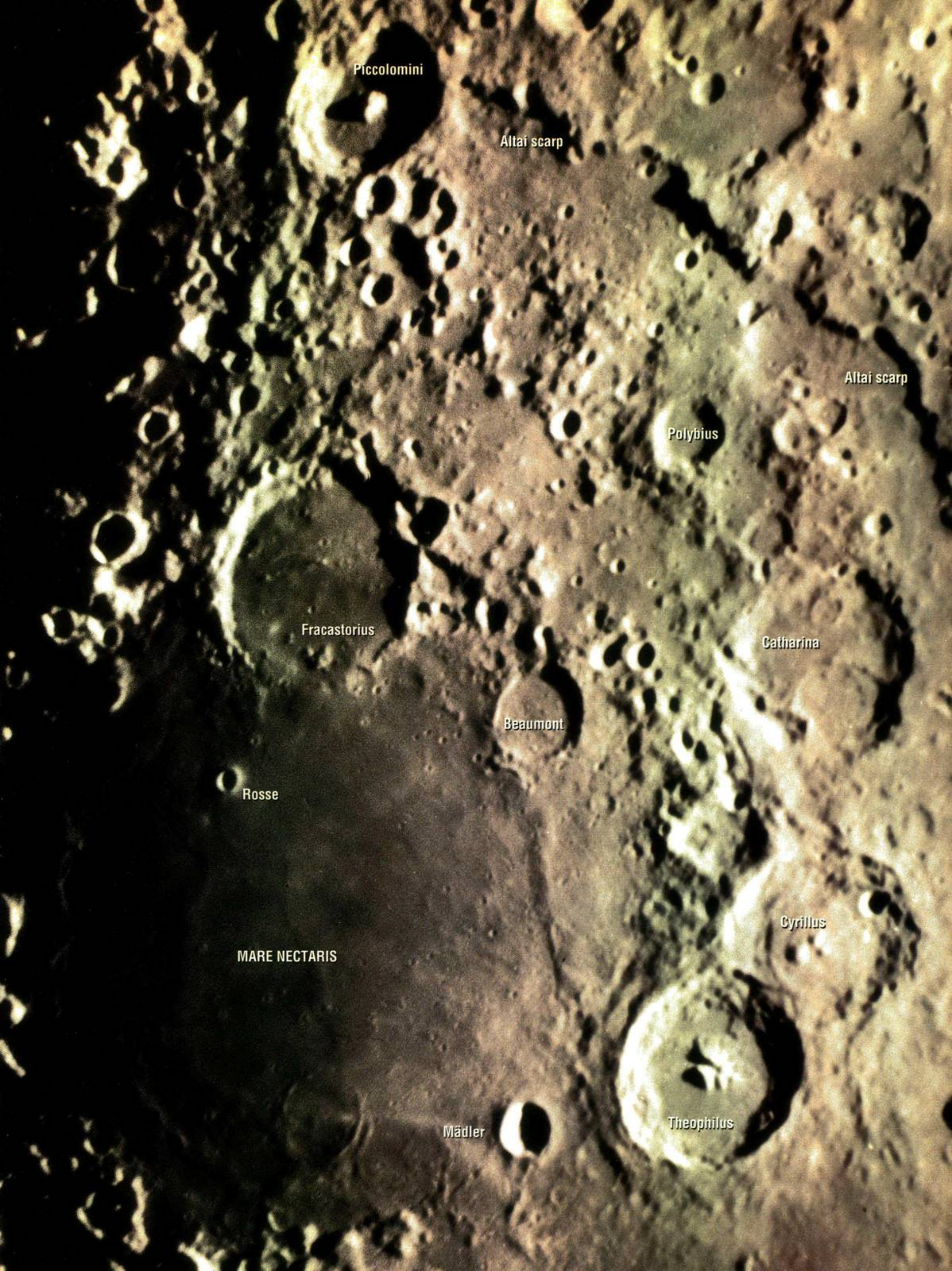
A BROKEN-DOWN BULL'S EYE, Mare Nectaris preserves many traces of its violent birth almost 4 billion years ago.

West of the mare lie three magnificent craters to explore at highest power. North to south, they are Theophilus, Cyrillus, and Catharina. Each is about 100 km in diameter, and all have intricate features inside: central peaks, craterlets, terraces, and rilles. Cyrillus and Catharina are probably as old as Fracastorius but they escaped the mare floods because they lie away from the basin's bottom. Theophilus, however, is much younger according to scientists — perhaps as much as 700 million years younger. You can see how it burst into the wall of Cyrillus, deforming it and casting debris across the older crater, softening its relief.

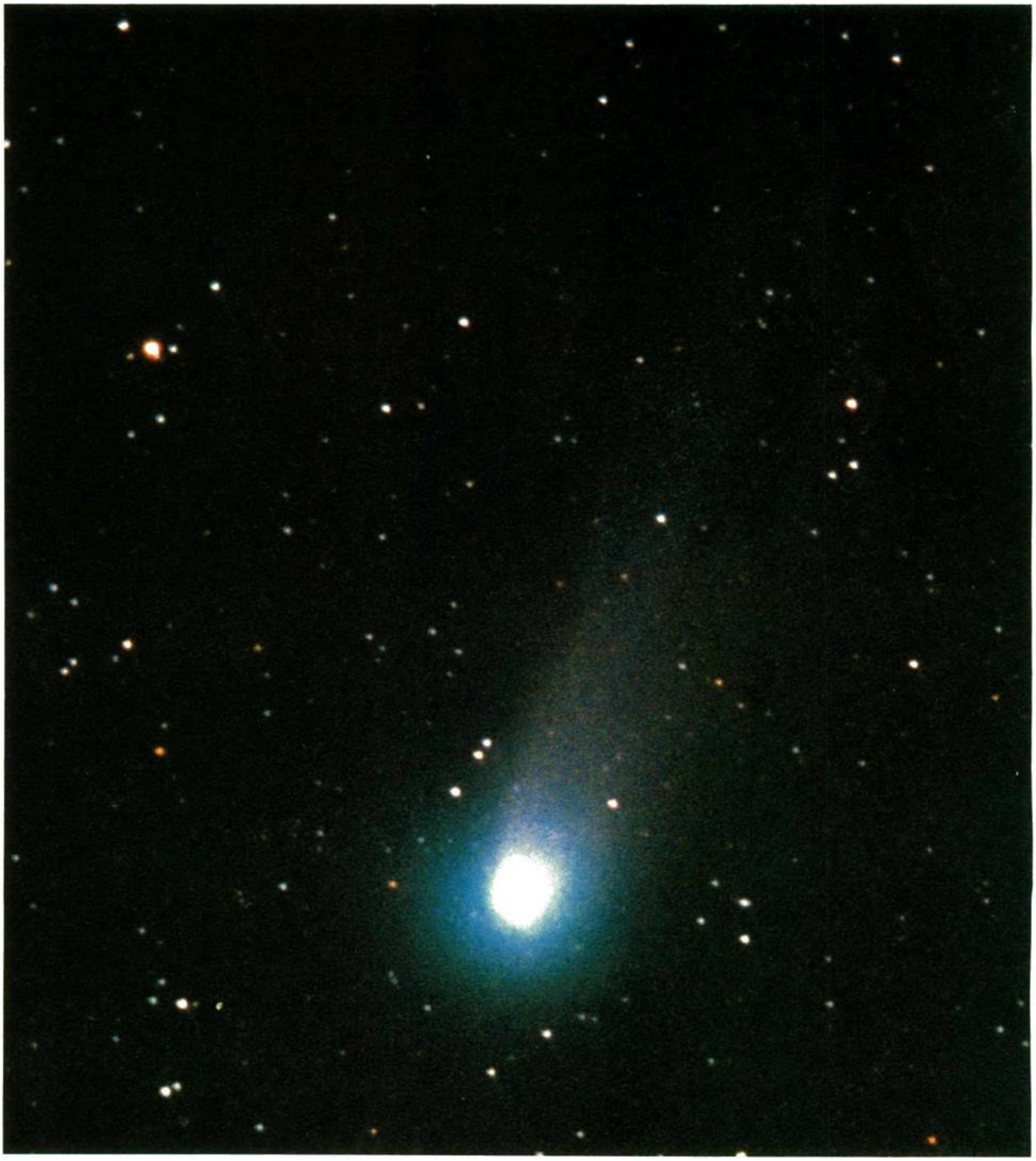
You'll find the youngest craters in the region among the smallest ones. Use high power on a night of steady seeing and roam the hills as well as the mare. Look for small sharp-rimmed craters. Some, but not all, have light ejecta aprons around them. One such is Rosse, 12 km across. It stands in lonely splendor on the mare near the eastern "horn" of Fracastorius.

Before you leave the Mare Nectaris region, settle down and take a last low-power view. See it whole. Trace the ring scarps and mentally fill in the missing sections. As you cruise over the craterscape, try to imagine the titanic energies released here and marvel at its deathly stillness today. ☐

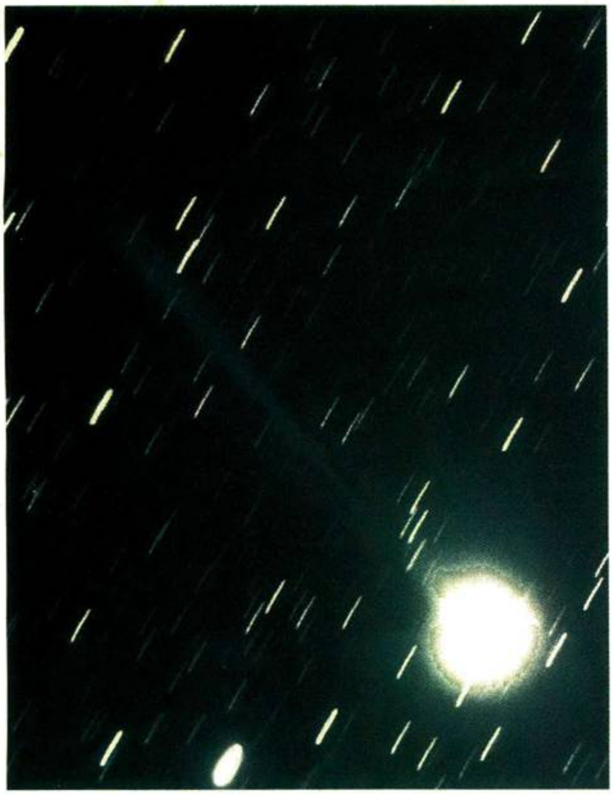
Jean Dragesco


Piccolomini
Altai scarp
Altai scarp
Polybius
Fracastorius
Catharina
Beaumont
Rosse
Cyrillus
MARE NECTARIS
Mädler
Theophilus

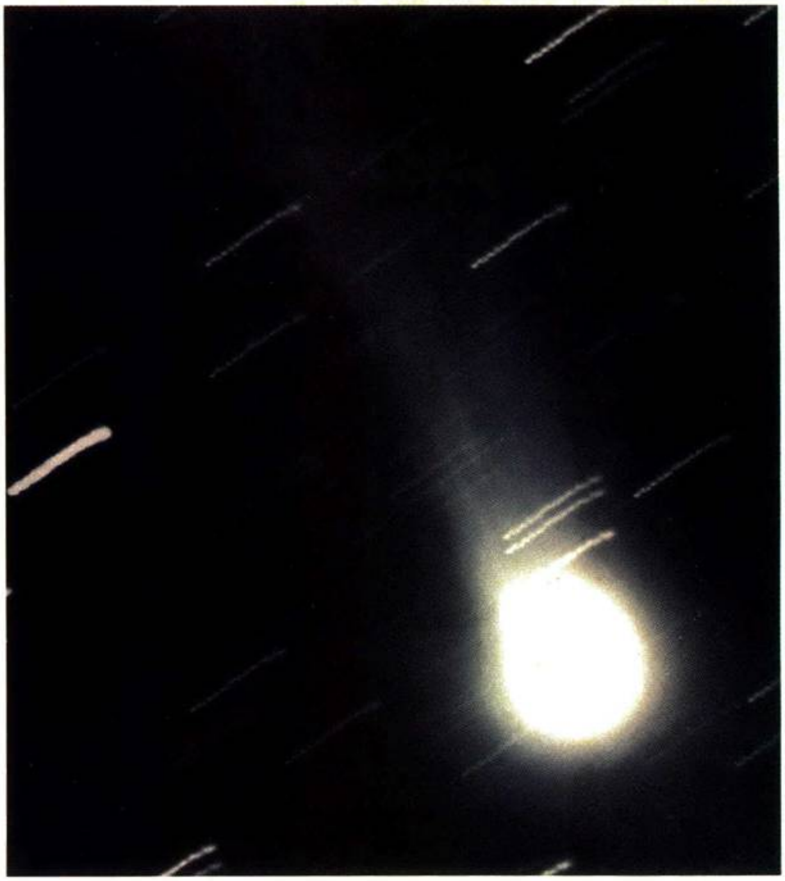
Observers around the world captured striking images of the comet that spawned the Perseid meteor shower.



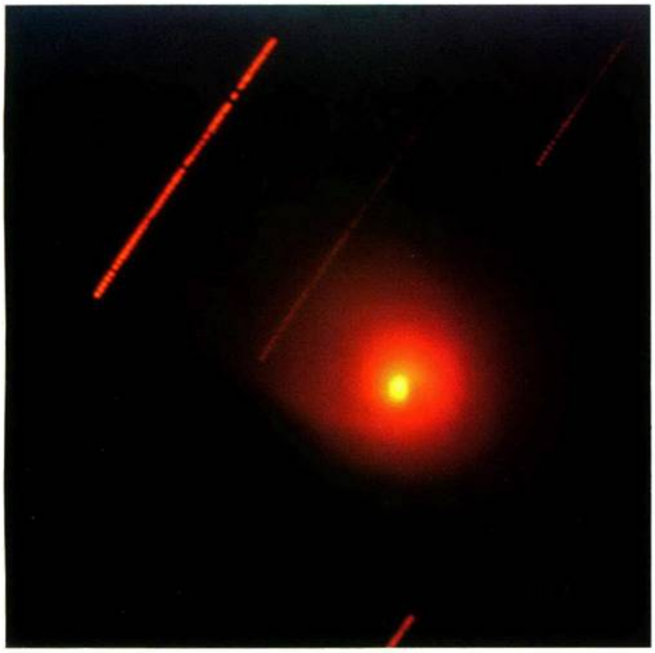
Its bright coma and graceful tail made Swift-Tuttle a prime target for Chris Cook on November 27. Cook used an 8-inch f/10 Schmidt-Cassegrain at f/6.3 and an 8-minute exposure on Fujicolor Super HG 400 to capture the 5th-magnitude comet.



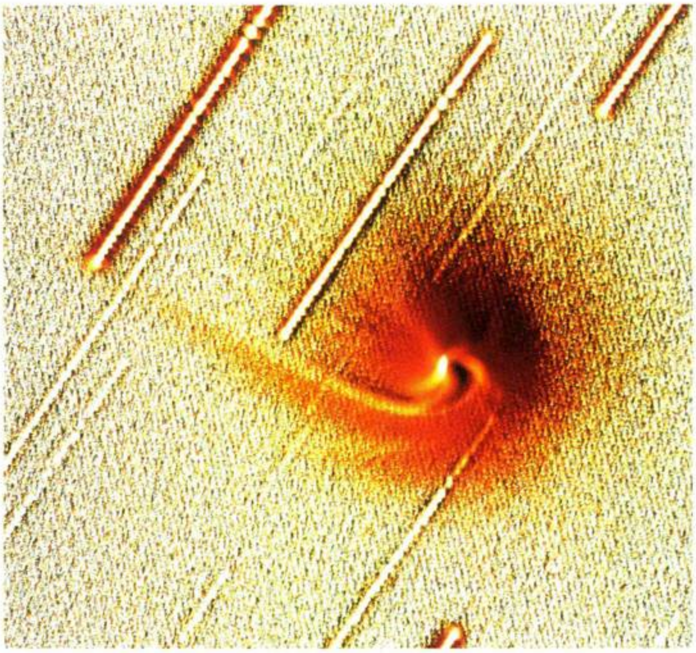
A long spike punctuates the highly structured tail of Swift-Tuttle around mid-November. Martin Mobberley shot this view on November 13 with a 14-inch f/5 Newtonian and a 24-minute exposure on hypered Tech Pan.



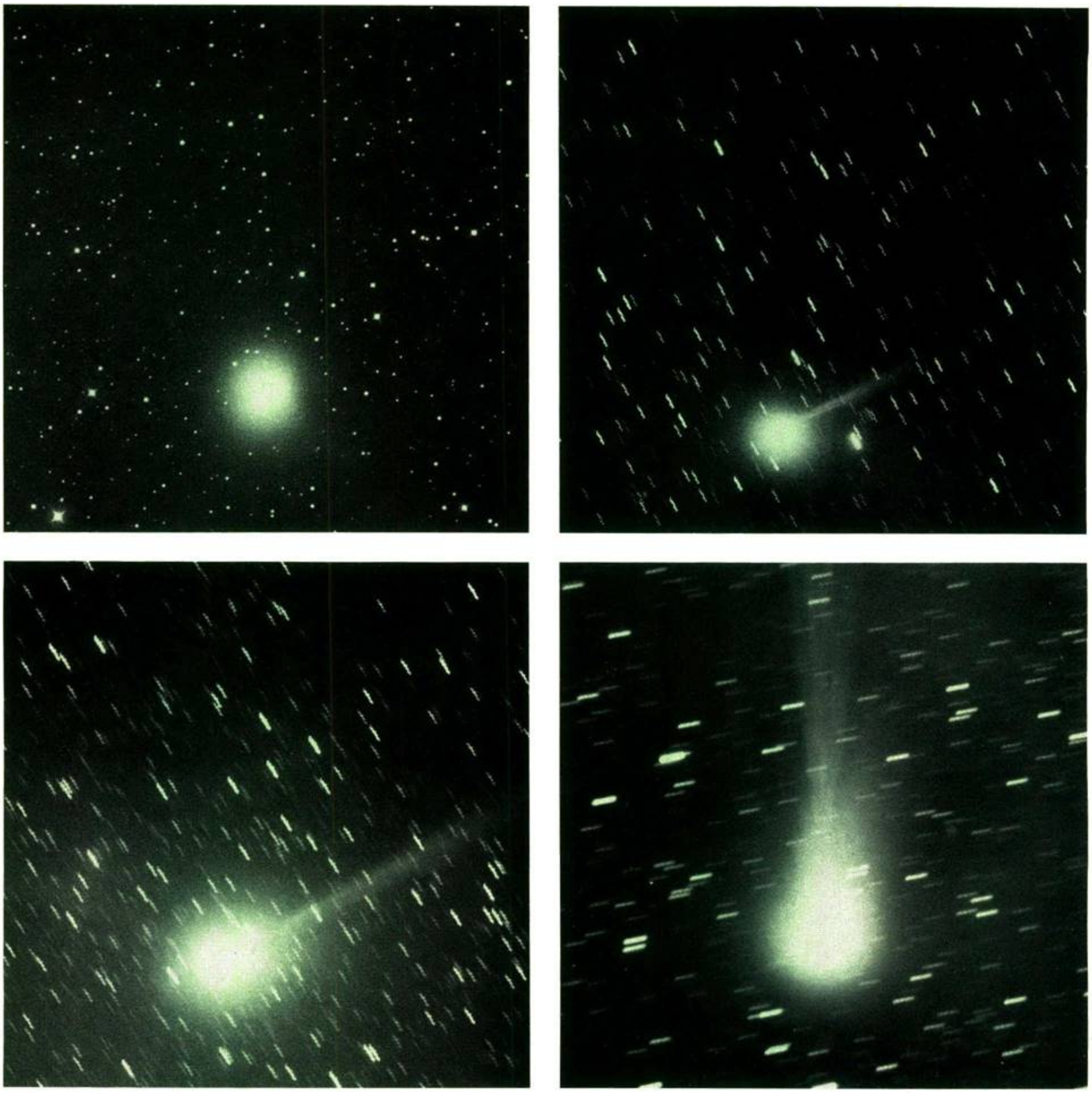
Several streamers highlight the complex ion tail captured in this November 27 photo by James Foster. He used an 11-inch Schmidt-Cassegrain at f/11 and a 56-minute exposure on hypered Tech Pan to capture this rich detail.



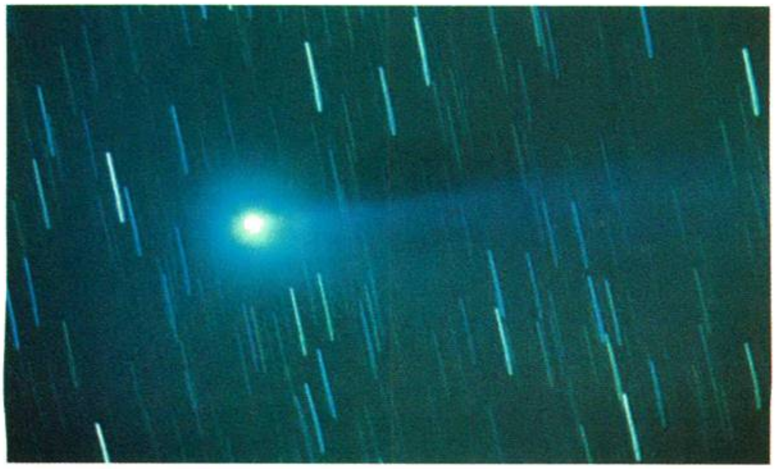
A strange corkscrew tail appeared on November 30, when James DeYoung and Richard Schmidt imaged Swift-Tuttle with a CCD camera on the U.S. Naval Observatory's 24-inch reflector in Washington, D.C.



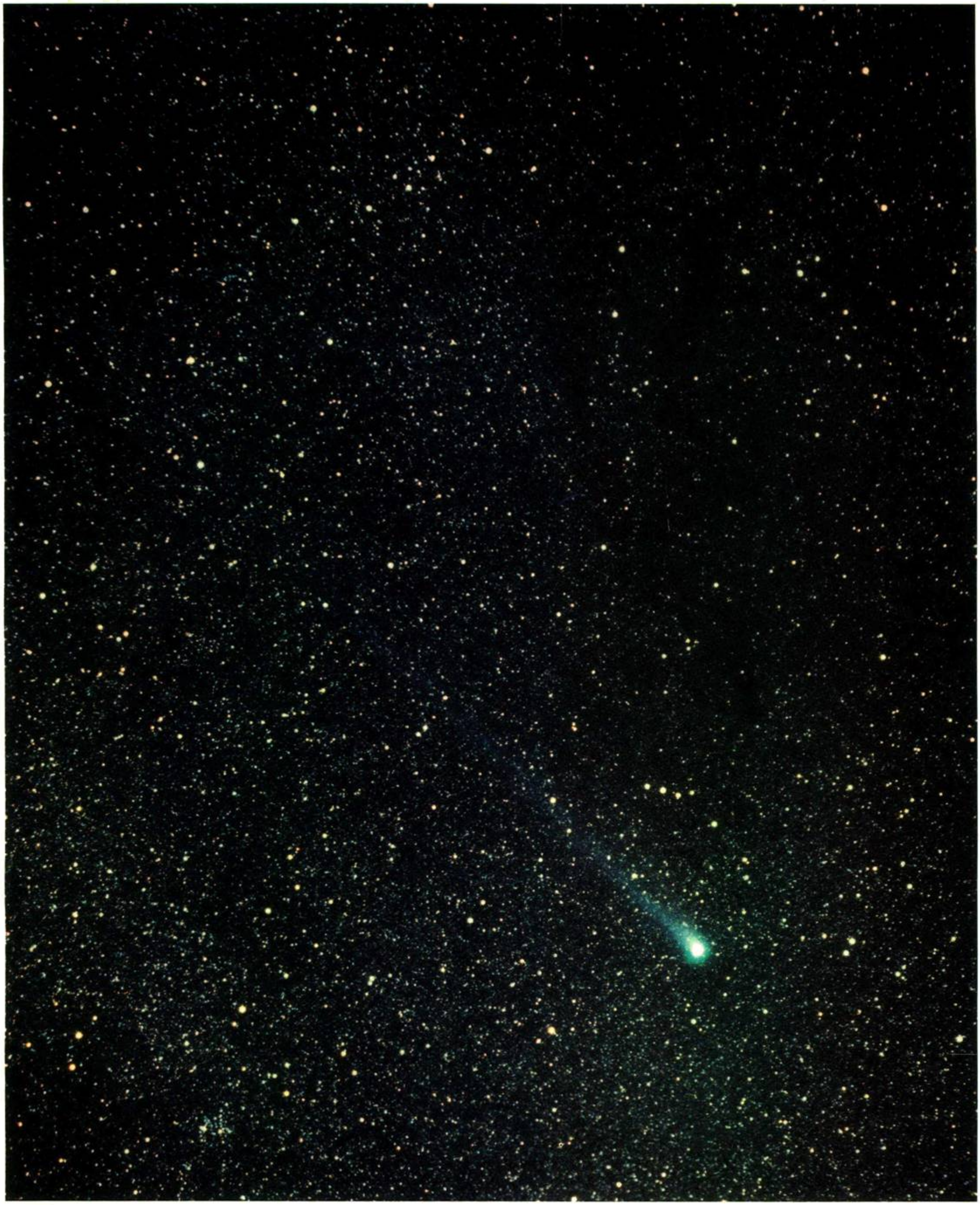
An enhanced view of the image at left reveals even more fine detail in the comet's jets.



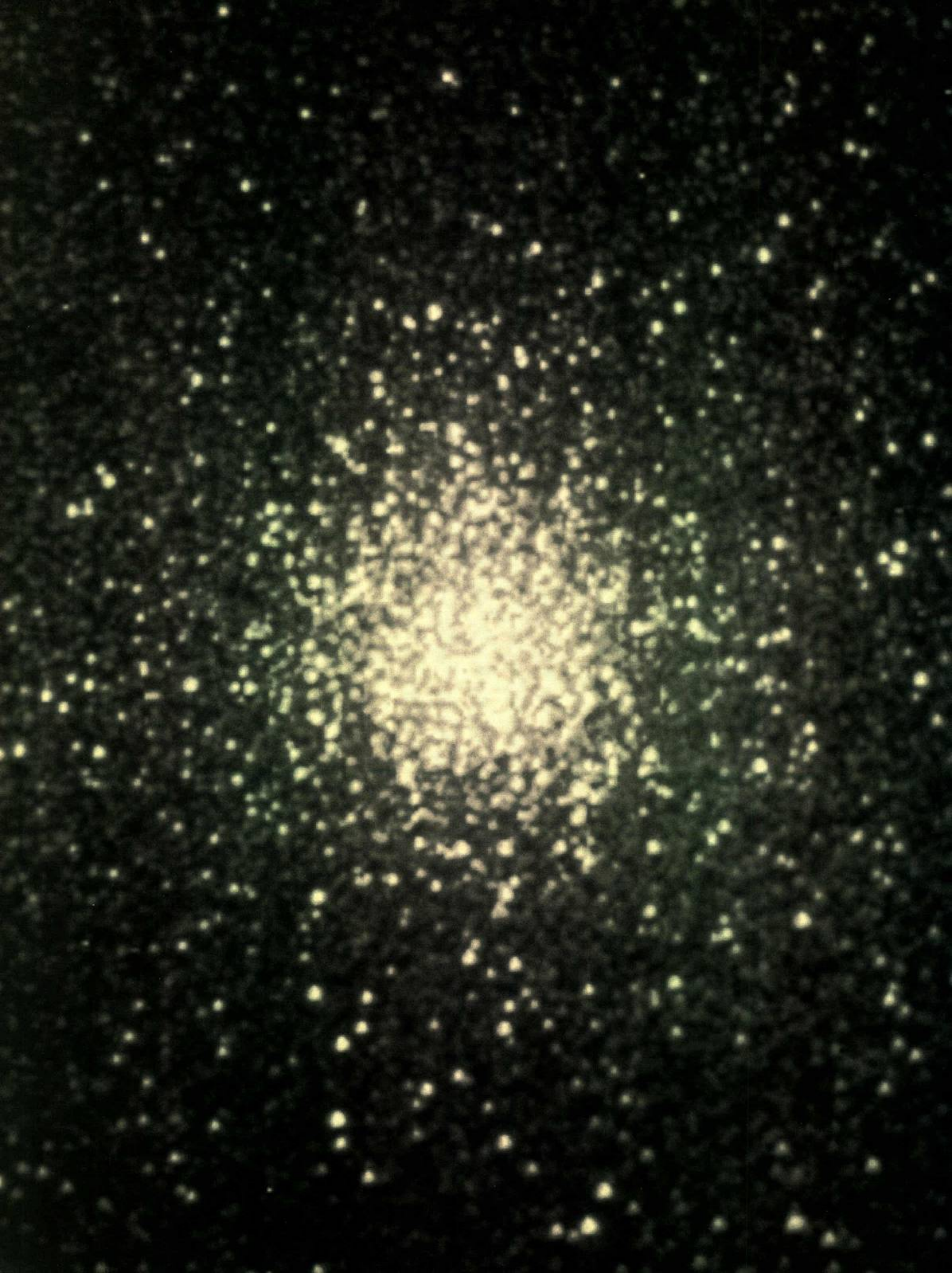
The tail evolved dramatically during late October and November. The comet displayed a nearly non-existent tail on October 25 (top left), a short, straight tail on October 31 (top right), a longer, slightly more structured tail on November 14 (above left), and multiple tails on November 27 (above right). Michael Stecker used an 8-inch f/4 telescope for the first three photos and an 11-inch f/5.5 scope for the last one, shooting all images on hypered Tech Pan film.



Glowing molecules of gas, stripped from the comet's nucleus and flowing away from the Sun, trace Swift-Tuttle's ion tail on November 20. James Foster took the photo with an 11-inch Schmidt-Cassegrain at f/6.3.



Swift-Tuttle cuts through a rich Milky Way starfield near the joint borders of Hercules, Ophiuchus, and Aquila in Gerald Rhemann's photo from November 24. Rhemann took this 18-minute exposure with a 7-inch Schmidt camera on Ektachrome 100 film.



THE DIGITAL DARKROOM

"PRINTING" THE IMAGE

Computers and image-processing programs are providing astrophotographers with powerful new tools for bringing the most out of astronomical images.

by Richard Berry

It is a dark and stormy night — hardly a time for astronomy. Yet images of the starry universe glow before you on the computer screen. You can hardly wait to see the pictures you took with your friends during that long night of imaging with their CCD camera.

One of your friends now leans toward the computer screen. She checks the logbook and its list of the calibrated images they prepared a few days earlier. After a moment, she proclaims, "Let's start with NGC 7479."

Little is visible as the image scrolls down the screen. A few stars glow dimly, and you see a dark gray patch at the center of the screen. That's the galaxy. Your other friend is already moving a crosshair pointer across the screen to read pixel values. As the glowing pointer moves over the screen they change: over the sky the numbers lie in the low hundreds; as it sweeps over the galaxy the count tops 1,000. "Good numbers," he grunts. She turns and reminds you, "A count of 65,000 shows on the screen as pure white, so the 1,200 reading we have for the nucleus of the galaxy looks awfully dark. But watch this. . . ."

The pointer touches a control and the screen swiftly lightens. "I'm setting 1,500 to display as pure white and 200 as black. That'll show us what's in the galaxy." Although you've seen it happen many times before, you still gasp as the glowing image of a galaxy emerges from darkness. "Great shot," you say, breaking into a smile. "Great shot!" Then it dawns on you — "Hey, is this one of the pictures you asked me to guide?"

Digital Magic

Last month's "Digital Darkroom" talked about how to get the best digital "negatives" from a CCD camera. That process, akin to taking and developing a photographic negative, involves taking special dark frames and flat-field frames at the telescope that you then use to electronically subtract noise and imperfections from your hard-won CCD images. The result: a clean, noise-free file called a "calibrated image." But assembling calibrated image files is just the first step to creating stunning images from a CCD camera.

The next step is image processing — the digital equivalent to printing a negative. In the traditional darkroom, you would use different grades of paper and techniques such as dodging and burning to make the best possible print from a negative.

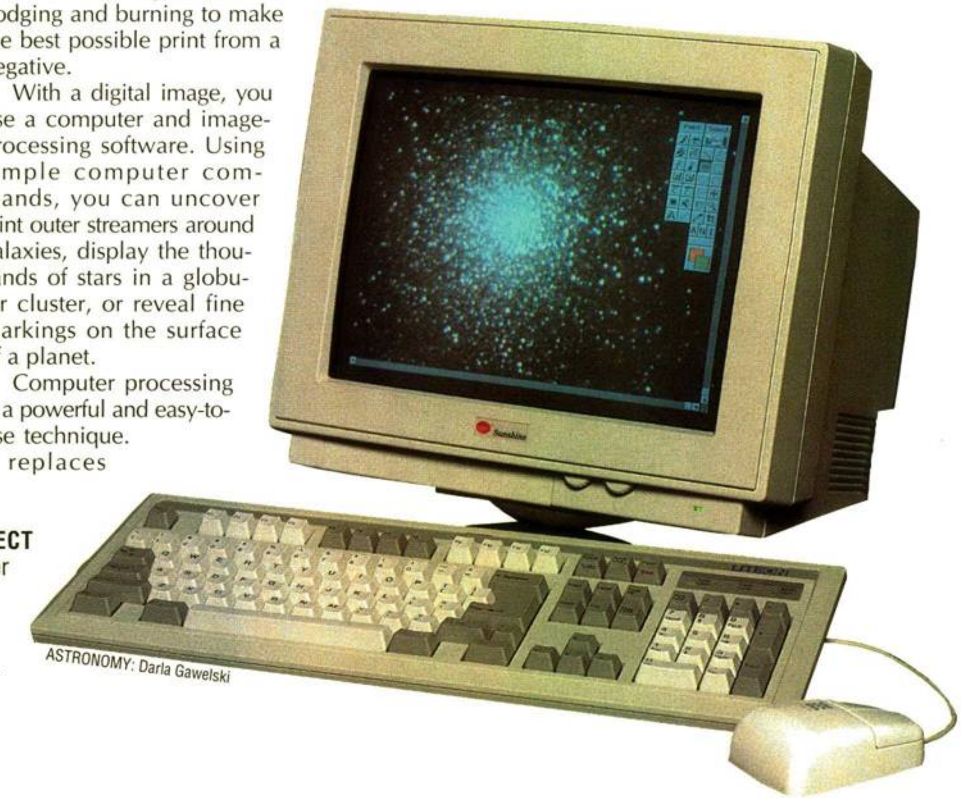
With a digital image, you use a computer and image-processing software. Using simple computer commands, you can uncover faint outer streamers around galaxies, display the thousands of stars in a globular cluster, or reveal fine markings on the surface of a planet.

Computer processing is a powerful and easy-to-use technique. It replaces hours of fastidious darkroom work with quick clicks of a mouse. Image-processing software allows you to display all the details hidden in the original image, from the bright cores of galaxies right out to the faint tendrils of their spiral arms.

Fortunately, computer processing is not restricted to users of CCD cameras. New technologies such as low-cost slide scanners and Kodak's Photo CD process now make it possible for you to convert any photograph, be it slide film or negative, into a digital image. Once it's in electronic form, you can apply the same computer processing magic to a photograph as CCD camera owners can to their frames. The digital darkroom has arrived for all astrophotographers.

Painting By Numbers

Image processing works because,

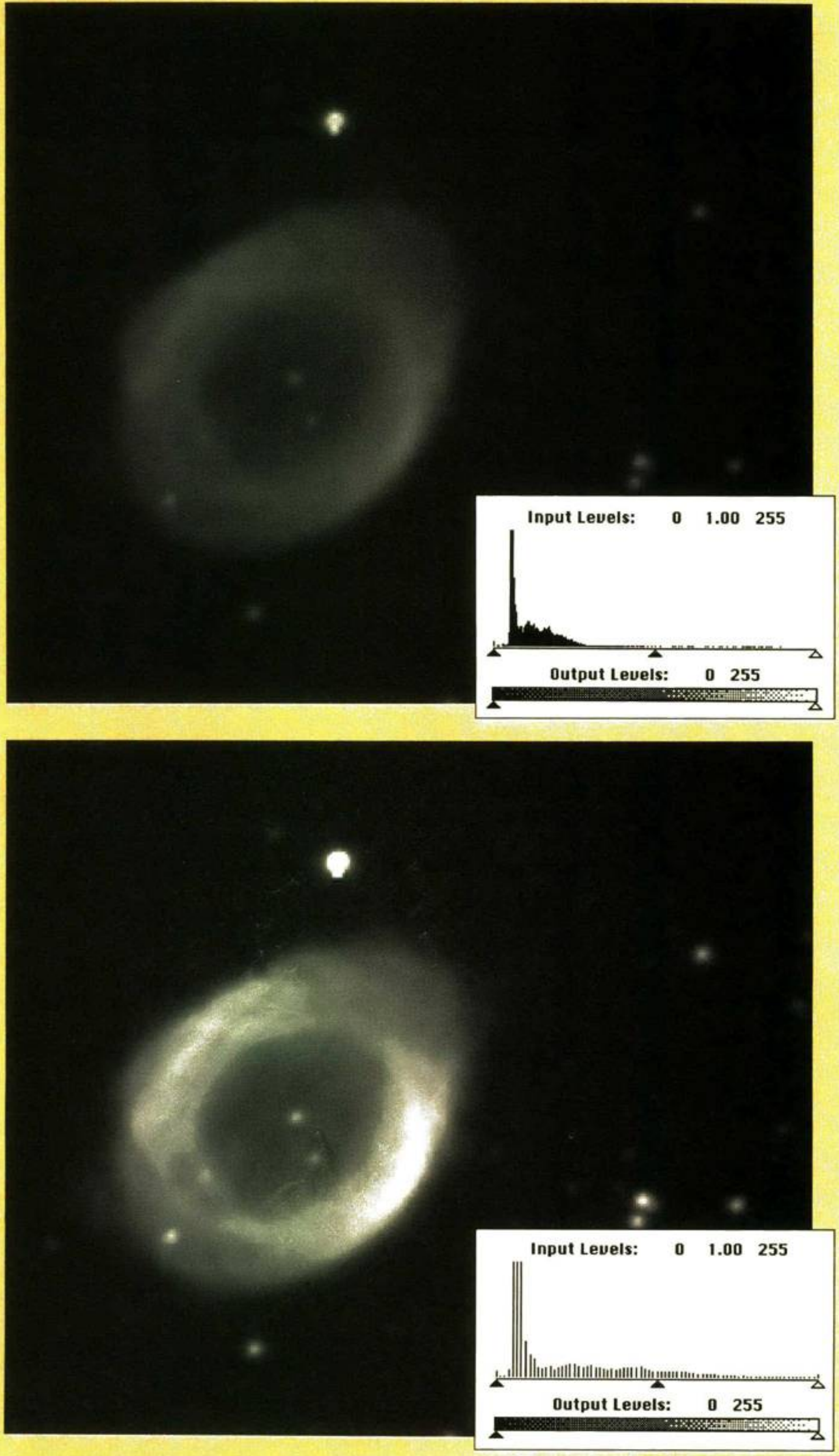


ASTRONOMY: Darla Gawelski

Jack Newton / image processing by Richard Berry

THE CHALLENGE WITH PRINTING AN OBJECT like a globular cluster is showing the faint outer stars without burning out the bright core. But processing the image with a computer makes the task easy. This image of M13 was taken with an ST-6 CCD camera attached to a 25-inch telescope.

Stretching an Image



THE RAW IMAGE OF THE RING NEBULA at top shows a flat, gray image that looks underexposed. The graph of the number of dark and bright pixels shows that most pixels cluster at the dark end of the brightness scale. In the bottom image, the main cluster of pixels has been stretched out across the entire brightness range. Now the object pops out of the background.

to your computer, a digitized image is nothing but a pile of numbers. When it reads these numbers from a floppy disk or hard drive, your computer doesn't see a picture. All it does is add, subtract, multiply, and divide the numbers that make up the image. Changing the numbers can make the image brighter, give it contrast, or enhance faint structures that are barely visible to the eye.

The simplest change you can make is a linear "stretch." Here's the idea: with an image from a 16-bit CCD camera, for example, the brightness of objects can extend over a range of 65,536 steps. Zero would be pure black, 65,535 would be pure white. If you were to survey all the pixels that make up a typical image of a deep-sky object, you would find that most pixels lie between a low value representing the sky and a high value representing the brightest stars. The brightness of most pixels falls in a narrow range, perhaps no more than 1,000 steps wide, just above the brightness of the sky.

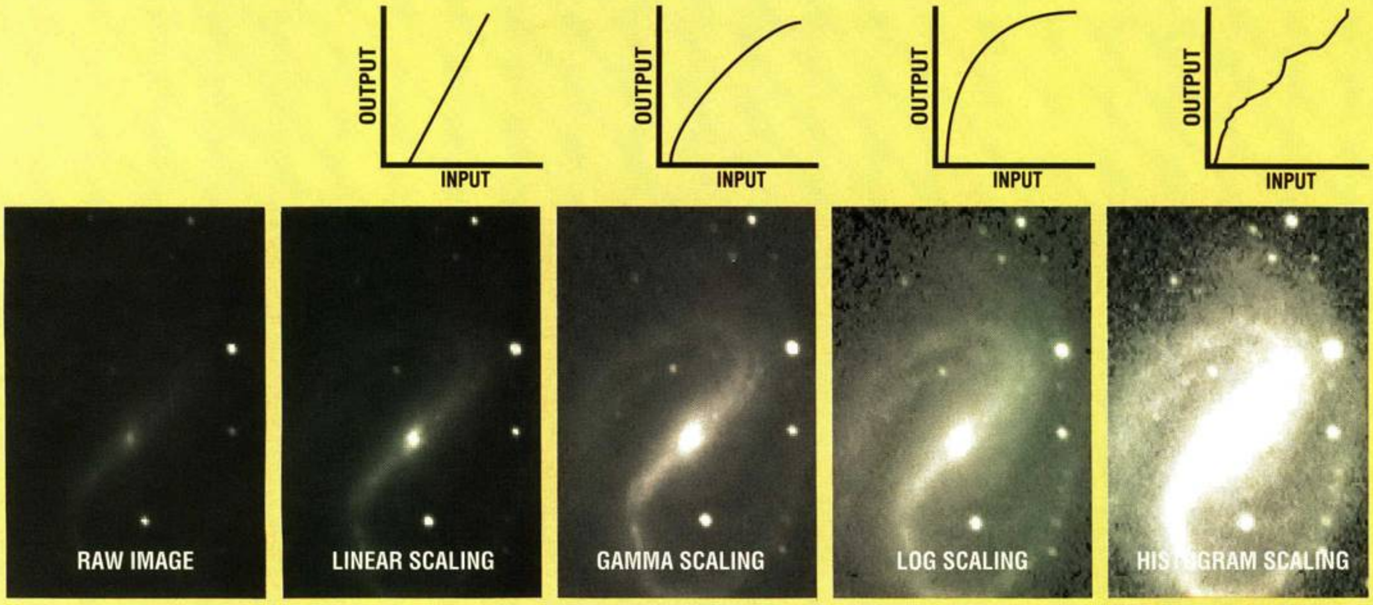
When you first call up your galaxy shot, for example, the computer displays step 65,535 as white. But only a few overexposed stars actually have that brightness. The core of the galaxy has a brightness level of only 1,200. It looks dark gray. The spiral arms are fainter still and barely show up. The sky itself has a level of 200.

What you'd like is to display the sky as black (a screen brightness of 0%) and the galaxy core as white (a screen brightness of 100%). To do this you perform a linear stretch. You set 200 to display as 0% and 1,200 to show as 100%, effectively throwing away information in the pixels with values higher and lower than these numbers.

In a linear stretch, the computer assigns a screen brightness of 0% to the low pixel value and a screen brightness of 100% to the high pixel value and then creates a table listing all the intermediate pixel values. If the low value is 200 and the high value is 1,200 there are 1,000 pixel values in the image. To stretch the brightness equally between 0% and 100%, the computer assigns 10 pixel values to each 1% increment in display brightness. If you graphed the relationship between the original pixel value and its brightness on your screen, the graph would be a straight line. That's why this stretch is called linear.

Linear stretches work wonders whenever the range of pixel values is fairly short — no more than a few hundred pixel values. This is the case with many faint deep-sky objects and with CCD images that are technically

Ways to Bend and Stretch



Jack Newton / image processing by Richard Berry

THERE ARE SEVERAL WAYS TO STRETCH AN IMAGE. Each brings out different levels of detail. In the raw CCD frame the galaxy, NGC 7479, is almost invisible. A linear stretch, like the one done to the Ring Nebula on the opposite page, reveals the galaxy but shows little faint detail.

A STRETCH CALLED GAMMA SCALING can boost the faint details more than the bright parts. It makes the spiral arms prominent while retaining the starlike core. Log scaling reveals even more faint outer details, while a custom histogram stretch produces a different result.

underexposed. A linear stretch takes objects that look dull gray and rescales them over the entire brightness range. Parts that should be bright turn white, while faint parts look dark.

However, when the range of brightness in the original image is wide, too many pixel values must be stuffed into each step in the display brightness scale. Details in the darkest or brightest parts of the image can remain hidden. To extract this detail, you use non-linear stretches.

A Revealing Image

Your friends are well into their evening of image processing. Now he's scanning the crosshair over the image looking at pixel values beyond the outermost turn in the spiral arms. "The sky background far away from the galaxy has a pixel value of about 210, but you can see the areas just outside the image are brighter than the sky — they run 230 or so. That means there's stuff out there we can't yet see. That's what I want to get."

They consult momentarily. Terms like "gamma" and "log" pass between them. They've made a decision. He clicks the mouse on a menu, selects Log, and the image changes dramatically. She turns to you and whispers, "I still can't get over how much faint stuff surrounds galaxies. In all the years we did photography, we never got negatives that showed the spiral arms anything like this. I just love it."

As Easy as Calling Up a Log

When your friends wanted to see the faint, outlying parts of the galaxy better, they considered two possibilities: gamma scaling (sometimes called power-law scaling) and logarithmic scaling. In gamma scaling for deep-sky objects, the computer doesn't stretch the brightnesses uniformly across the full range. Instead it stretches the brightness more at the low end. That makes features with low pixel values (faint parts of galaxies for example) brighter on the screen. But the non-linear stretch keeps the bright parts such as the cores of galaxies from becoming too bright and burning out into one mass of white.

If you were to plot a graph of input pixel values versus output brightness, as most image-processing programs can, you'd see that the so-called gamma curve suitable for most deep-sky objects is not a straight line but bows upwards — the curve rises at the low end then flattens. Most of the time, this type of curve provides the most aesthetically pleasing rendition of deep-sky objects.

A gamma curve can also bow the other way, flat at first and then rising at the high end. This type of curve is useful for planetary images — it stretches the contrast between bright features on the planet while preventing the dark limb of the planet from becoming too dark and blending into the sky.

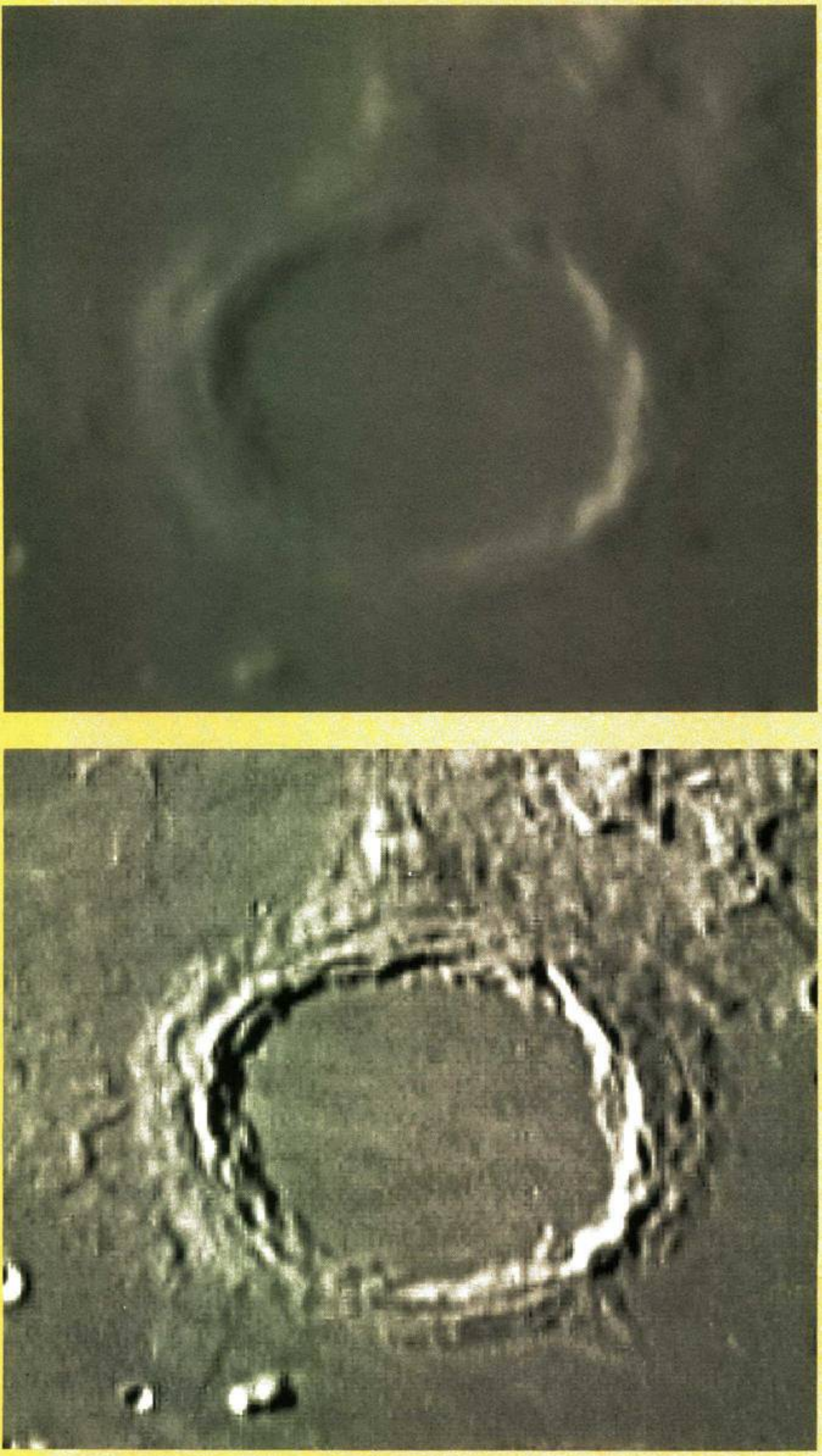
Logarithmic scaling acts much the same as gamma scaling but is harsher than even the most extreme gamma curve. A typical log curve rises steeply at the low end and then quickly flattens out. Your friends select log scaling when they want to bring out the faint haloes around galaxies without burning out the spiral arms. Although log-scaled images can reveal hidden details remarkably well, the resulting images often look unnatural.

Another stretching variation is "histogram scaling." Here you use the computer to construct a custom-made curve that force-fits all the pixel values onto a curve with a shape best suited for that object. Histogram scaling is even more dramatic than log scaling — it's usually too powerful for galaxies but does wonders in revealing impossibly faint features like the outer envelopes around planetary nebulae.

A Lunar Odyssey

The wind still howls and sleet rattles against the windows. But now you and your friends are exploring the

Sharpening an Image



Richard Berry

THE RAW IMAGE OF THE MOON at top shows the crater Archimedes as a blurry outline with little detail. Yet the detail is hidden in the image. Subtracting an even fuzzier version of the image called an unsharp mask removes the fuzziness. Like magic, a sharp image of the lunar surface (bottom) emerges. Unsharp masking is an important tool for extracting the detail from images of the Moon and planets.

surface of the Moon. This is the second time you've taken this lunar excursion; your first journey was two weeks ago at the telescope. In all your years of lunar observing you'd never seen anything like it. Individual craters filled the CCD frame. The detail was remarkable. Every few seconds a new image appeared; to save a good one, you pressed a function key. You went a little nuts and left your friends with 15 megabytes of lunar pictures.

Tonight you're back to look over the images, and to take home some copies of the best. You quickly click the mouse twice and a picture of the crater Archimedes pops onto the screen. The picture looks good to you just as it is.

"That's a nice image," she comments, "but we can make it a lot better." She stares intently at Archimedes for a moment. "It needs a soft mask . . . oh, about 7 pixels square I'd say. Look, here's how you can tell. See how the light from this bright crater rim diffuses about 3 or 4 pixels out? The fuzziness is everywhere, but you're going to fix that."

"Click on Filters and then Unsharp Mask," he suggests. "Then click '7 by 7.'" You do as you're told, noting that there must be a dozen filters and a dozen choices besides 7 by 7.

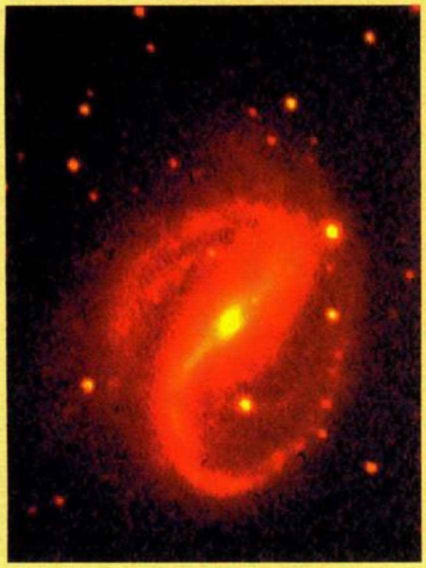
A moment later the image of Archimedes clears. It's as if someone pulled a sheet of waxed paper off the screen. The fuzz evaporates and Archimedes stands sharp-rimmed with craterlets on its floor.

Fun with Fuzzy Filters

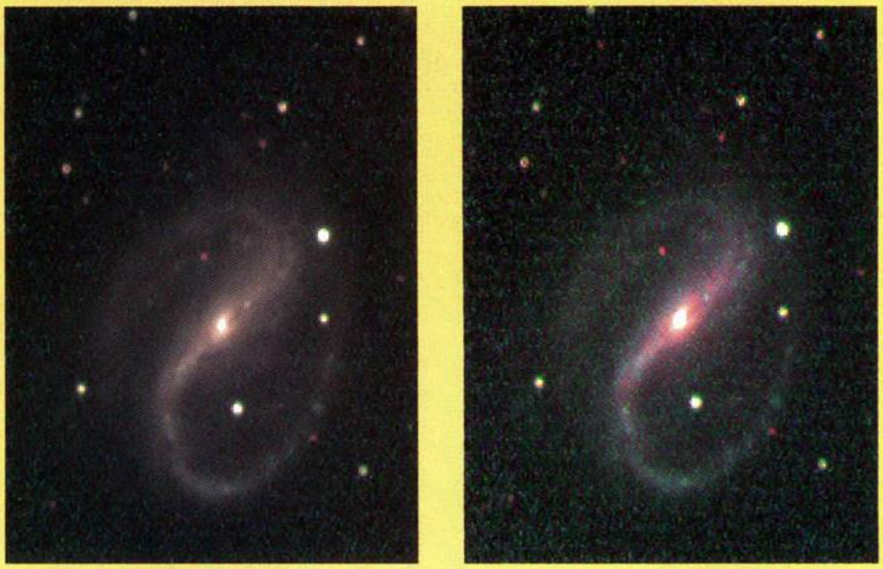
If there were no atmosphere and every telescope were perfect, there would be less need for image processing. As light from the Moon, planets, or stars passes through the atmosphere and optics of your telescope, it is spread out into a blur. Mathematicians say that the image has been "convolved." Image processing allows you to deconvolve the image and extract much of the original sharpness.

One technique useful to amateur astronomers is unsharp masking, a technique first developed for use in conventional darkrooms. In the digital version of unsharp masking what happens is this: When you give the computer a blurry image for unsharp masking, it builds an even fuzzier image by averaging each pixel with nearby pixels. In the case of a 7 by 7 mask, for each pixel in the original image the computer averages the 48 pixels around it and makes that the new pixel value in the new image. This new image is the un-

Ways to Add Color



CCD CAMERAS PRODUCE BLACK-AND-WHITE IMAGES. Like colorizing an old movie, it's possible to add an arbitrary palette of colors to a single image. Bright parts get assigned one color, faint parts another. Although useful for studying intensity levels, false-color images can look garish and artificial.



CREATING TRUE-COLOR IMAGES with today's CCD cameras requires electronically combining images taken through red, green, and blue filters. Many deep-sky objects contain only subtle colors. Turning up the color saturation creates an exaggerated "enhanced color" image.

Jack Newton, image processing by Richard Berry

sharp mask. The computer then subtracts this fuzzy image from your original image. Like magic, the image sharpens.

To understand how an unsharp mask works, think about what would happen if you added a fuzzier version of your image to the original. You would get an image that looks even blurrier.

Now imagine *subtracting* the fuzzy version. The fuzzy parts cancel, leaving only the "unfuzzy" elements. Sharp features remain intact. Lunar craters pop out sharp and clear and Jupiter's cloud belts reveal a wealth of detail. The main trick is getting the mask size right. It should be equal to or a little larger than the blurring effects you're trying to eliminate. Too small and it has little effect; too large and it can produce dark haloes around every bright object.

Building Color

It is late now and the storm has subsided. Light snow still falls and you and your hosts are tired. Yet one other imaging feat beckons: a color picture. Your friends had taken pictures of NGC 7479 through blue and green filters, and the picture that you guided was shot through a red filter. You have everything you need to make a color picture.

A bit foolishly you brag, "Watch this. It'll be easy." You bring all three images onto the screen. The green and blue images are nearly identical, but the red image, your image, is rotated compared to the other two. Bravely, you select a menu item you saw earlier that sounded like it was for merging images.

The menu looks obvious. For each color there's a size, a rotation, and two positions. You gamble and type 45 into the Rotation box then click OK. A badly messed-up color picture appears on the screen.

"Good guess," she says. "You're close with the angle. But it looks like the red image is still too far right and a touch low." It takes a little more nudging and rotating but three tries later you have it. The three images snap together.

"But there isn't much color," you say, looking glumly at the pale image you have worked so hard for. "It's all pastels."

"That's true," she agrees. "The universe doesn't make colorful galaxies." Sensing your frustration, she says, "OK, go ahead. You can increase the color saturation if you want. Just keep it tasteful."

A Digital Toolbox

Creating color photos by combining three black-and-white images is one more technique borrowed from the world of conventional photography. With film negatives, however, it can take hours of fussing in the darkroom. With a computer, building a color composite takes mere minutes. (See "Going Digital in Color," July 1992 ASTRONOMY, for more details.)

Like sharpening and contrast stretching, color compositing is one of the tools now available to users of image-processing software. None of these techniques is used alone. Getting the most out of digital images involves a combination of these and other tools of the digital darkroom.

And more powerful techniques are coming. New affordable programs are on the horizon that will bring to the amateur astronomer tools similar to the software being used to sharpen images from the Hubble Space Telescope. Amateurs will soon be able to extract every pixel of detail from their original images. All of this, thanks to the digital darkroom. □

Richard Berry is the author of the new book Choosing and Using a CCD Camera *(Willmann-Bell, Inc., 1992) and is developing a new color-capable version of his Astronomical Image Processing program.*

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LUMICON Cassegrain EASY-GUIDER f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation	**$395**

MEADE STARFINDERS

8" f/6
$649*

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6" f/8 Starfinder 6(add $50 P&S)	**$569**
8" f/6 Starfinder 8 (add $60 P&S)	**$649**
10" f/4.5 Starfinder 10 (add $75 P&S)	**$759**
16" f/4.5 Starfinder 16 (ship. freight COD)	**$1995**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

Meade #43 Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$399**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

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LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

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IMPROVED!—5500 Additions / Corrections

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Improved NGC SKY VECTOR with over 12,000 object memory including complete, corrected RNGC catalogue, IC catalogue, complete P&K planetary catalogue, and much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$129.00**
2" Adapter for Hasselblad	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	***$129.00***
2" rack & pinion focuser, only 2" high	**$139.00**
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2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
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1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing, threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

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LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Galaxy NGC 4631 and companion NGC 4627 in Canes Venatici. 60 minute photo by Eraldo Guidolin (in Padova, Italy) using an 8" f/10 telescope, a LUMICON Cassegrain Easy-Guider at f/6 and hypered 2415 film. Mr. Guidolin stated, "With your Cassegrain Easy-Guider I have taken hundreds of perfectly guided high quality photographs."

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Genesis 4" f/5 4 element fluorite	$1595
Pronto 70mm f/6.4 apochromat w/2" diagonal	$749
Pronto 70mm f/6.4 w/Porro prism	$689
Complete Equatorial Mount	$795
Motor Drive for above mount	$239
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	$89
1.8x or 2.5x Tele Vue Barlow Lens	$89
2" Giant Barlow - 2x	$189
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$219
15mm Wide-Field, 1¼" eyepiece, 65°	$135
19mm Wide-Field, 1¼" eyepiece, 65°	$145
24mm Wide-Field, "superb," 65°	$169
32mm Wide-Field, 2" eyepiece, 65°	$239
40mm Wide-Field, "awesome," 65°	$299
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, Type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$289
20mm Nagler, Type II, 82°, 2" only	$340
1¼" Paracorr Visual Coma Corrector	$159
2" Paracorr Visual Coma Corrector	$249
NEW! 22mm Panoptic 1¼"/2", 68°	$249
NEW! 35mm Panoptic 2", 68° field	$325

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$49.00**	**$39.00**
52, 55, 58, 62mm	**$59.00**	**$49.00**
67, 72, 77mm	**$69.00**	**$59.00**
82mm	**$79.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$39.50** 1.52" **$45.00** 1.83" **$49.50**
2.14" **$59.50** 2.60" **$75.00** 3.10" **$99.50**

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90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

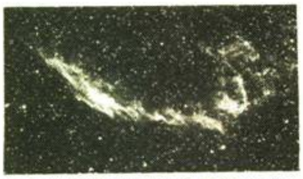
AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

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BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

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0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
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48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
2" Rear Cell Filter, fits SCT's Deep-Sky, **$119.50** UHC, O-III, H-Beta,	**$199.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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U.S. Patent 4,473,636

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
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U.S. Patent 4,448,500

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Full aperture. Installs in seconds. Specify 2" or 1¼".

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3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

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Pentax 6X7 **add $119;** Pentax 645 **add $139**

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For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

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Adapter for Hasselblad **$198,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

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For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$229,** Mamiya 645**$129**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

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Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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DEEP SKY JOURNAL # 4

FEBRUARY/MARCH 1993

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The sky's no limit to you, the deep sky astronomer, so don't be limited by what you read! Each issue of ***DEEP SKY JOURNAL***, takes you beyond the solar system to the far reaches of the visible universe, from your own backyard. The ***JOURNAL*** is dedicated to the preservation of the traditions which began 10 years ago in the old **DEEP SKY** magazine. The topics focus on finding and describing deep sky phenomena with various sized instruments, and recording those images in notes, sketches, and astrophotography. Subscriptions are $24 annually (6 issues) and $30 (U.S.) for Canada and Overseas.

DEEP SKY JOURNAL
6210 Karjala Road
Aberdeen, WA 98520
(206) 532-0711

FAST ASTEROIDS AND DARK ECLIPSES

December was a busy month for backyard astronomers. In addition to Comet Swift-Tuttle's final showing (see page 68 for photos), the near-Earth asteroid 4179 Toutatis raced across the sky and the Moon slid through Earth's shadow.

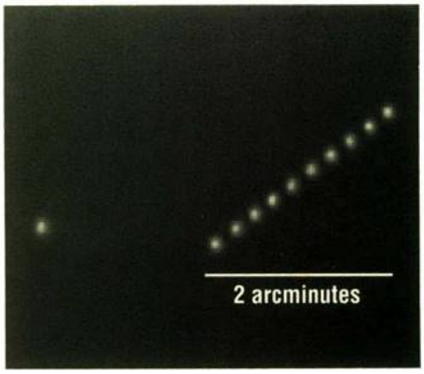
The December 9 total eclipse of the Moon was the highlight for many observers, at least where winter weather cleared to provide a view. "When it became obvious that the weather was not going to be favorable from my home in Young Harris, Georgia," says Jimmy McGinnis, "I hit the road about noon on eclipse day. The cloud cover never broke and as darkness fell I had all but given up hope. Then while heading east on I-40 just past Winston-Salem, I saw the greatly distorted orange disk of the Moon rising in front of me. Screeching to a halt, I quickly set up my video camera on the side of the highway to capture the eclipse on tape. Was it worth the 260-mile panic flight? You bet! Seeing the Earth's shadow on the rising Moon gave me the impression I could hold my hand up, wave, and see my own shadow projected across space on the lunar surface."

For those who saw totality, it was the darkness of the Moon that most impressed readers. "The eclipse was as dark as expected — I'd say 0.5 to 1.0 on the 5-point Danjon scale," estimates Benjamin Gomes-Casseres. "But I was not prepared for the bright rim of the umbra. In contrast, the next part of the umbra was very dark, and then the part of the Moon deeper in shadow, which should have been the darkest, seemed brighter and more brownish." Many observers commented on this effect, one no doubt caused by a layer of volcanic aerosols still lingering in our atmosphere from Mount Pinatubo's 1991 eruption.

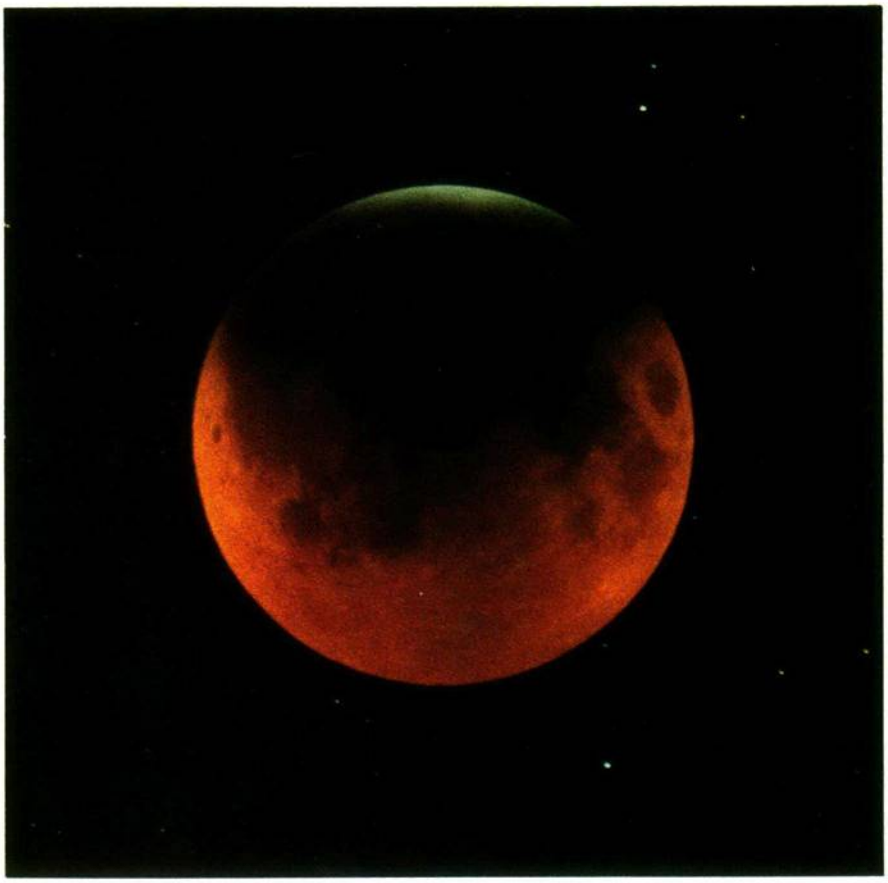
The volcanic debris made this the darkest total lunar eclipse in a decade. "At mid-eclipse," reports Robert B. Slobins, "the Moon was about as bright as nearby Eta, Iota, or Theta Aurigae, and about two magnitudes fainter than the Pleaides, or about magnitude 3.5 to 4.0. The central umbra was dark enough to obscure all lunar surface features. I saw no reddish color on the Moon through the finder of my telescope. With the naked eye, the Moon was a fuzzy patch of gray-white. Still, this was one of the prettiest eclipses I have seen."

In early December, backyard astronomers witnessed another unusual sight — a solar-system body moving fast enough through their telescope fields they could see motion "in real time." The object was Toutatis, a small Earth-crossing asteroid (see page 36 for details). Robert Melvin and Bill Gladson recorded Toutatis' motion in a series of CCD images taken on December 13, 5 days after its closest approach of 2.2 million miles. To capture the flyby, Melvin and Gladson used a 24-inch telescope at the University of North Carolina and a 512x480-pixel CCD camera. ☐

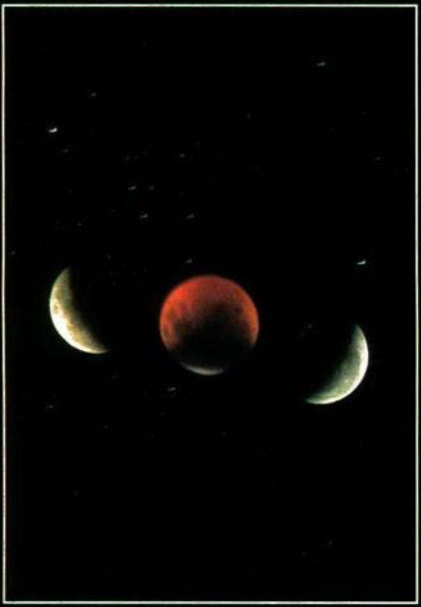
ASTRONOMY wants to hear about your observations. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187



FAST-MOVING TOUTATIS, an Earth-approaching asteroid, appears as a series of dots moving past a star in this composite of 10 CCD images taken by Robert Melvin and Bill Gladson. The duo took the 10-second-long exposures one minute apart.



DARK SHADOWS played across the face of the Moon last December during the darkest total lunar eclipse in recent years. Thomas R. Perry captured the view at mid-totality using an 8-inch f/6.3 SCT and a 50-second exposure on Kodacolor 1600 film.

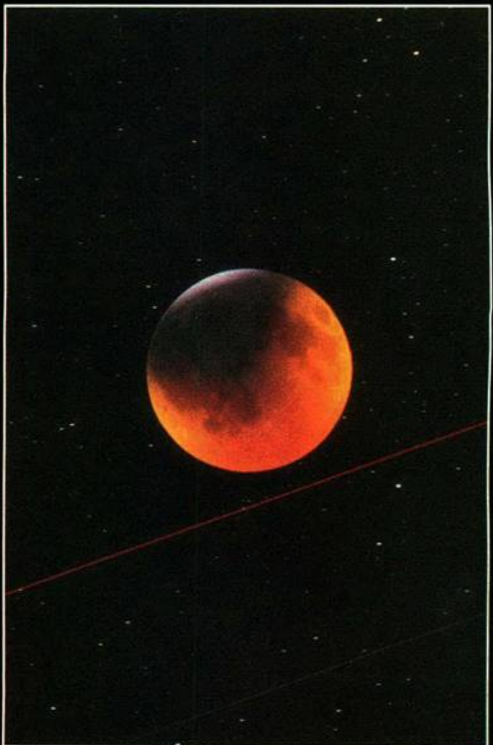


AN ECLIPSE TO REMEMBER

On the night of December 9, backyard astronomers across the Western Hemisphere gazed in wonder on an unusual sight — a ghostly gray-red Moon suspended in front of a backdrop of stars. The occasion was the first total lunar eclipse seen in this part of the world since August 1989. To record the event, Paul Shulins set up his camera and 24mm wide-angle lens on top of the 52-story Prudential Building in Boston. His 23 exposures captured the entire eclipse on one frame (opposite page) that nets Shulins this month's $100 "Best Astrophoto" award.

The darkness of this eclipse proved a challenge to all astrophotographers. John Rozakis and Nicolas Matsopoulos of Athens, Greece, had to use a 90-second exposure (bottom right) with their 6-inch f/5 reflector to capture the eclipsed Moon — along with an aircraft that happened through the frame. Terence Dickinson of Ontario, Canada, switched to a fast 300mm telephoto for his 75-second exposure (bottom left) of the eclipsed Moon among the stars. Benjamin Gomes-Casseres of Lexington, Massachusetts, used a 400mm telephoto (left) for a triple exposure of the Moon passing through Earth's shadow. Jimmy McGinnis drove from Georgia to North Carolina to find clear skies so he could record the eclipse with his Canon L-1 video camera (top left).

Farther west, Moon watchers saw the Moon rise already in eclipse. In California, Ralph J. Merletti watched the Moon rise over a desert landscape still lit by the glow of twilight as the partial eclipse ended (top right).



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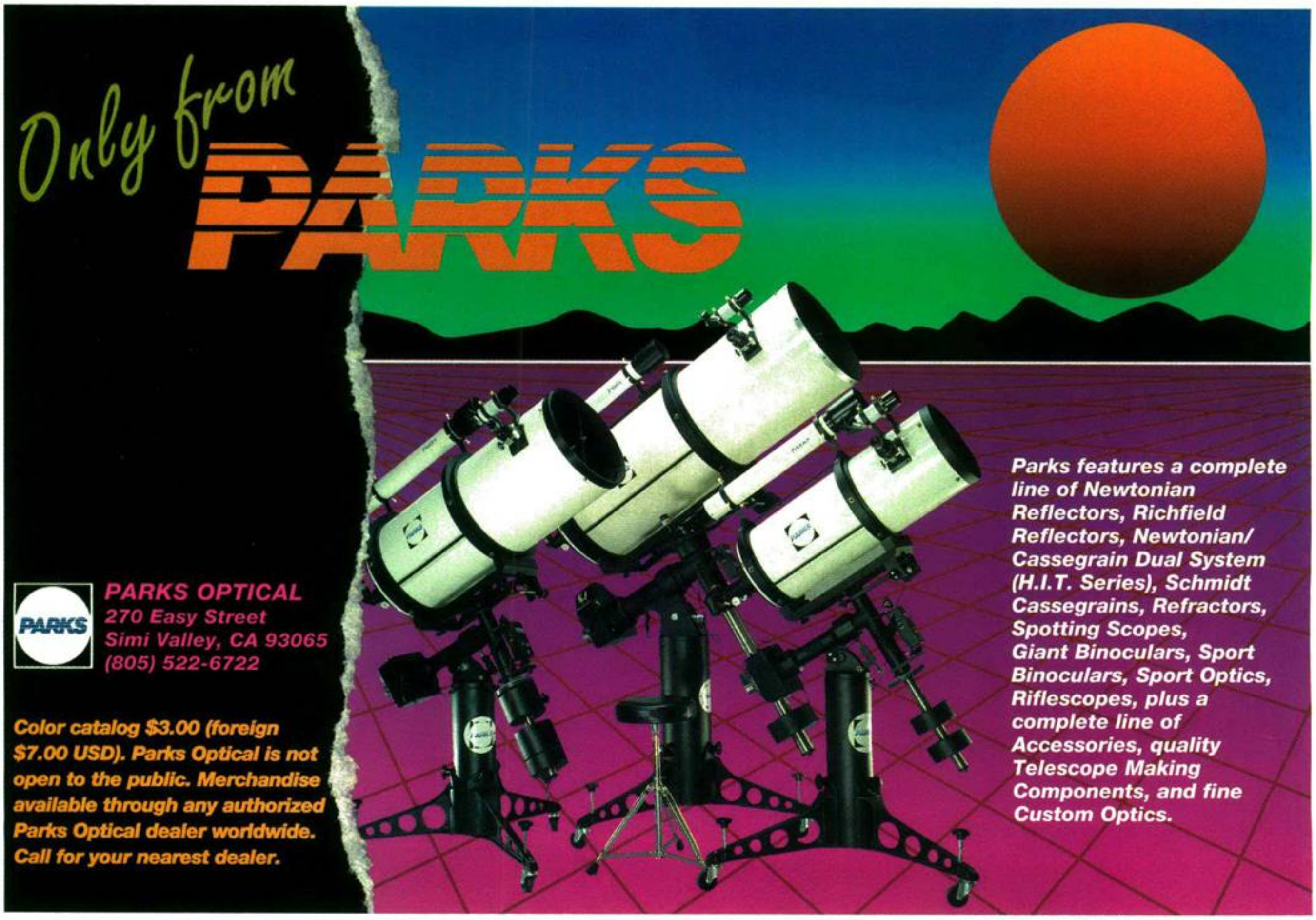

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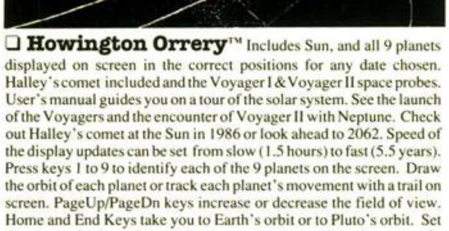

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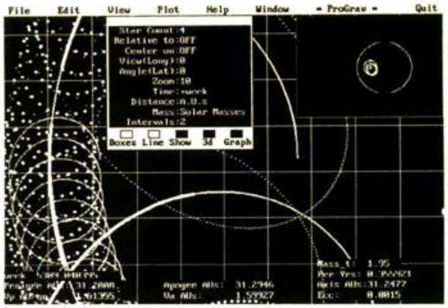

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Relative to:OFF
Center on:OFF
View(Long):0
Angle(Lat):0
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Distance:A.U.s
Mass:Solar Masses
Intervals:2

Perigee AU: 31.2000
Apogee AUs: 31.2946
Va AUs: 1.59927
Mass_t: 1.95
Per Yes: 0.355921
Axis AUs:31.2477
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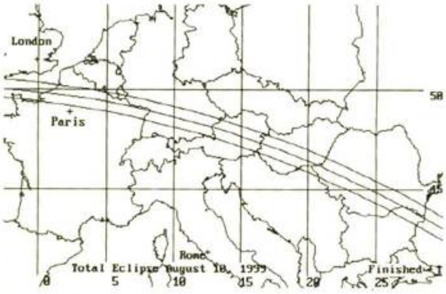

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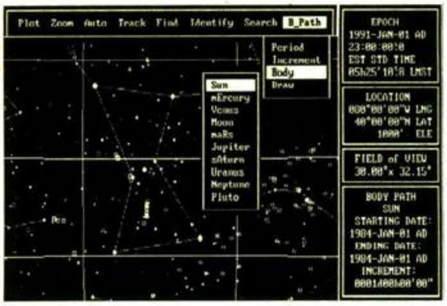


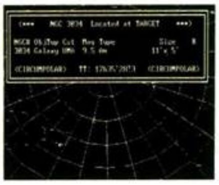
EPOCH
1991-JAN-01 AD
23:00:00:0
EST STD TIME
05h25'10"0 LMST

LOCATION
000°00'00"W LNG
40°00'00"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"

Partial Solar Eclipse
Magnitude: 0.170 Obscuration: 0.3%
LAST CONTACT



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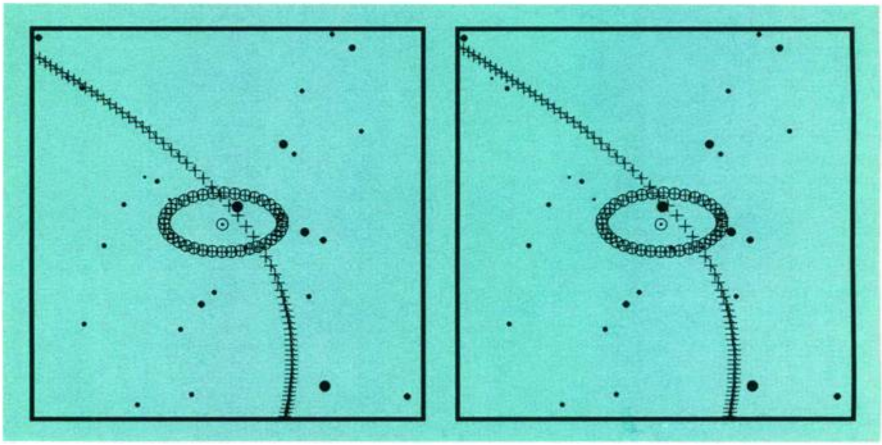

COMET SWIFT-TUTTLE SWEEPS around the Sun and intersects Earth's orbit in this 3-D image pair from Deep Space 3-D.

Deep Space 3-D (3.03), *David Chandler Co., P.O. Box 309, La Verne, CA 91750. Phone (714) 988-5678. Shareware; registration: $79. Minimum requirements: IBM PC-compatible computer, 512 KB memory, CGA display and hard drive with 2.5 MB free. Supports Epson-compatible 9- and 24-pin dot matrix printers and HP-compatible laser printers. A 3-D viewer is included.*

As you would expect from a program with 3-D in its name, Deep Space 3-D will print three-dimensional maps of star fields and the orbit of a comet around the Sun (sorry, no 3-D screen images). While it's fun and instructional to look at a map of Orion and see depth or to view how Comet Swift-Tuttle intersects Earth's orbit, this program does much more than the novel printing of maps. Observers will find many useful features in Deep Space 3-D.

"What's Up Today" gives lunar phases, positions and visibility of the planets, and a list of which comets are visible. You can choose several different styles of sky maps — including galactic and ecliptic (plane of the solar system) coordinates — and whether to display comets and planets. You can not only select which types of deep-sky objects to plot and choose limiting magnitudes for both the stars and deep-sky objects, but also edit the sky map to include only those particular objects you wish to observe. As you edit the map, you can add labels to the objects to help in their identification at the eyepiece and add comments to an observing log kept for each object. The labels and object editing result in a customized sky map. If you add descriptions to the map while you're observing, you also have an observing log that you can keep in your files.

A feature of interest to beginning star watchers and binocular users is the "Match the Sky" map mode. You can create a map of any constellation at a printed size that will match the star patterns as they appear in the sky. No longer do you have to guess how big a star pattern is or where a binocular object is compared to a bright star.

The program comes with a database of over 19,600 stars (down to magnitude 7.25), the entire NGC catalog, the Saguaro Astronomy Club database, and orbital information for several dozen comets. You can extend the stellar database to magnitude 8.9 for a total of 134,053 stars for $35, or to fainter than 10th magnitude for a total of 248,709 stars for $65. Orbital information for 1,100 comets costs only $15. For deep-sky observers who want the most from the program, these additional catalogs add significantly to the cost of the software.

One minor complaint is that the software doesn't support a mouse. A bigger complaint is that help isn't available within any of the program functions. Deep Space 3-D comes with only an on-line manual available at the opening menu. You can (and should) print out the manual sections you use most often, because you can't access help once you start to produce a map. I found the lack of a help function annoying as I tried to make and edit some maps.

Deep Space 3-D is a good program for comet and deep-sky observers. You can make maps that will show exactly what you want to look for at the eyepiece. And beginning astronomers can benefit from the "Match the Sky" maps. The price for the program is okay, but it is a tad expensive to expand the stellar database to its full size. — *Dave Bruning*

NEW SOFTWARE

***MegaStar**, E. L. B. Software, 8910 Willow Meadow, Houston, TX 77031. Phone: (713) 541-9723. Introductory price (doesn't include shipping): $139 for 5¼" high-density disks; $149 for 3½" high density disks. Minimum requirements: IBM PC/AT-compatible computer, 640 KB memory, hard drive, and VGA display. Math coprocessor and mouse recommended. Supports Epson dot-matrix and HP LaserJet IIP printer emulations.*

Make detailed finder charts and star maps with MegaStar. The stellar database includes over 15 million stars from the Hubble *Guide Star Catalog*, down to 15th magnitude in most regions. The non-stellar database contains over 80,000 objects, and you can add your own objects to this list. The total database contains over 50 MB of information. However, you can load smaller portions of the databases if you desire.

The maps plot non-stellar objects to scale with proper orientation for many galaxies. Field sizes range from 30 arcseconds to 20 degrees and you can draw an eyepiece field on the map. To produce effective finder charts, you can set the magnitude limits for both stellar and non-stellar objects. You can also search for objects and generate observing lists.

***Mission UFO**, Cliffs Notes, P.O. Box 80728, Lincoln, NE 68501-0728. Phone (800) 228-4078. $49.95. Minimum requirements: IBM PC-compatible computer, 512 KB free memory, hard drive, and VGA display. Includes both 5¼" and 3½" diskettes.*

A search for space-roaming aliens is the guise for this educational program about the solar system. Digitized NASA photos and drawings by space artist Ron Miller let you explore the planets. Use of the information in the data banks moves you up through 8 levels of play. Each program comes with an order form for a free Hansen Planetarium poster. ☐

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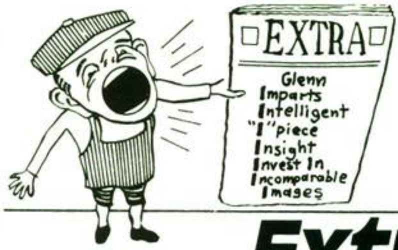

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NEW STAR LIST

Starlist 2000, by Richard Dibon-Smith, (John Wiley and Sons, Inc., 1992), ISBN 0-471-55895-8, 400 pages, acid-free paper, softcover, $29.95.

One mark of a good reference book is how often you use it — *Starlist 2000* has already passed my standard. I now consider it my book of choice when looking up stellar positions, magnitudes, and distances. Dibon-Smith conveniently lists by constellation over 2,400 stars brighter than magnitude 5.5 using Bayer and Flamsteed designations. He also gives for each star its *Henry Draper Catalogue* number, right ascension and declination for epoch 2000.0, apparent and absolute magnitudes, spectral type, distance, motions, parallax, diameter, and luminosity. Don't know the star's designation or constellation? Concordances listing stars by common name and by position (and therefore roughly by HD number) help direct you to the right entry.

A section on binary stars lists and describes wide doubles, colorful binaries, and visual binaries. This section contains a table that lists the orbital elements for over 75 visual binaries and drawings that show the orbits of 35 easily split binaries. Another section lists variable stars, giving for each star its type, period, magnitude range, and best viewing dates.

An appendix contains simple GW-BASIC programs for computing the day of the week from a Julian date, converting a Julian date into a calendar date and vice versa, and finding the transit time of a star and the approximate date of maximum brightness for a long-period variable star. The programs won't run under QuickBasic and do not check for input errors. Dibon-Smith gives sample calculations for each program for testing purposes. I personally would rather see these programs replaced in any future editions by additional star tables, because most of these programs exist elsewhere.

My only complaint about the book is the Flexibook binding. The softcover is okay, but it extends beyond the pages by about one-eighth inch. The corners on my copy are already dog-eared and it won't sit properly on my book rack. Aside from this minor point, I think *Starlist 2000* is a great reference book on the bright stars and will serve astronomers well. — *Dave Bruning*

General Astronomy

Fireside Astronomy, by Patrick Moore,

(John Wiley and Sons, 1992), ISBN 0-471-93164-0, 212 pages, hardcover, $24.95.

Over 100 short essays about space, astronomers, observatories, and astronomical objects compose this sequel to Moore's *Armchair Astronomy.* His topics include "Trouble at Woomera," about the British rocket program; "Astronomers and Joseph Stalin," about Nikolai Kozyrev; "Yerkes Observatory: The Bees and the Crickets," about the stone work at Yerkes; and "The Black Widow," about a pulsar in the constellation Sagitta.

Solar System

The Planets, by Nigel Henbest, (Viking, 1992), ISBN 0-670-83384-3, 208 pages, hardcover, $35.

In this coffee-table book, Henbest combines nontechnical text and 150 photos — 117 in full color — from NASA spacecraft to describe our present knowledge about each of the nine planets. He includes recent radar images of Venus obtained by the Magellan spacecraft.

Worlds in the Sky, by William Sheehan, (University of Arizona, 1992), ISBN 0-8165-1290-6, 243 pages, acid-free paper, hardcover, $35; ISBN 0-8165-1308-2, acid-free paper, softcover, $17.95.

Worlds in the Sky combines the results from spacecraft with visual telescopic observations to trace the history of planetary exploration. Sheehan weaves information obtained from the Mariner 9 and the Viking landers with the observations by Antoniadi and Schiaparelli. The voyage to the outer planets mixes data from Voyager 1 and 2 with the studies by Cassini, the Bonds, Lassell, Herschel, Slipher, and Tombaugh. Drawings and portraits accompany about two dozen black-and-white spacecraft images of the planets.

Other Books Received

The Interpretation of Modern Synthesis Observations of Spiral Galaxies, edited by Nebojsa Duric and Patrick C. Crane, (Astronomical Society of the Pacific, 1991), ISBN 0-937707-37-6, 275 pages, hardcover, $44.50. Proceedings from a technical symposium regarding the synthesis of images from radio telescopes such as the Very Large Array. ☐

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New Astronomy Products

1 "High Definition" Maksutov-Newtonian Telescope

Ceravolo Optical Systems has introduced the first in their new series of High Definition astronomical telescopes. The HD-145 is a 145mm (5.7-inch) f/6 Maksutov-Newtonian telescope optimized for high-resolution and high-contrast visual observing as well as CCD imaging. The instrument is designed to provide the image fidelity normally associated with apochromatic refractors but in a compact tube assembly. Each set of HD-145 optics is guaranteed to be diffraction limited and is accompanied by a computer-analyzed interferogram to document the unit's optical performance. Features include anti-reflection coatings on both sides of the Maksutov corrector lens, an 18 percent (by diameter) obstruction from the minimum-sized diagonal mirror, a 1-inch-tall low-profile focuser, and an all-aluminum tube with factory-set collimation. Mount shown not included.

Ceravolo Optical Systems, Ogdensburg, NY 13669-1427, (613) 258-4480, FAX (613) 258-3082. Introductory price: $1,699. Complete information and technical specifications: $2.

2 New Dobsonian Reflectors

Torus Optical now offers a series of Dobsonian telescopes designed to provide high image quality in a lightweight and portable package. The 12.5-inch f/5.6 model shown weighs just over 60 pounds (the heaviest single component weighs 40 pounds). A system of upper-tube clamps allows for quick assembly with no tools required. When broken down for transport, the scope fits into a compact car. The focal length of the telescope was chosen to minimize the central obstruction to 17 percent by diameter, yet the eyepiece height at the zenith is only 68 inches. The components are constructed of birch and mahogany plywood finished with 3 coats of marine spar varnish. The truss tubes are 1-inch aluminum covered with black foam pipe wrap. Bearing surfaces are "beige tweed" Formica against Teflon. Standard fittings include an 18-point primary mirror cell, Novak curved-vane spider, a Telrad finder, and an NGF focuser from Jim's Mobile. Torus Optical Dobsonians are also available in 14.5-inch, 16-inch, 18-inch, 20-inch, and 24-inch apertures.

Torus Optical, 67 Bon Aire, Iowa City, IA 52240, (319) 339-0524. 12.5-inch: $1,950; 14.5-inch: $2,350; 16-inch: $2,850; 18-inch: $3,450; 20-inch: $4,150; 24-inch: $7,250.

3 An Observatory Dome Kit

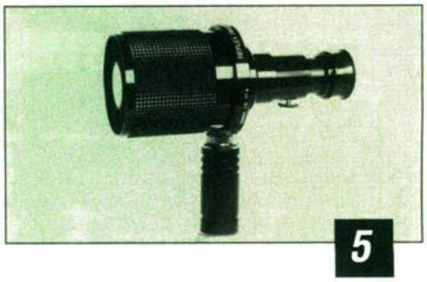
This new fiberglass observatory dome allows astronomers to create a permanent, protected observing site in a limited space. The new 6-foot model features a weather-tight design and a 30-inch wide shutter. The dome will accommodate up to an 11-inch Schmidt-Cassegrain or an 8-inch Newtonian. The Home Dome comes as a kit that includes instructions, stainless steel hardware, and all fittings. Except for drilling bolt holes, all finish work is done at the factory. The 6-foot Home Dome is available as a short model (height of 3'10") suitable for installation on existing structures as shown, or as a stand-alone tall model (height 6'10") that includes a wall and entrance door.

Technical Innovations Inc., 22500 Old Hundred Road, Barnesville, MD 20838, (301) 972-8040. Short model: $1,950; Tall model: $2,950.

4 A Year of Moon Phases

This annual wall poster depicts the phase of the Moon for each day of the year in a graphic layout. Times of the New and Full Moon are shown in universal time. Versions for both 1993 and 1994 are available in many museum gift shops and nature stores, and from mail order dealers. Posters may also be ordered directly from the manufacturer.

Celestial Products, P.O. Box 801, Middleburg, VA 22117, (800) 235-3783, FAX (703) 338-4042. $8.95 plus $3 shipping and handling. Quantity discounts available. Free catalog of astronomical products also available.



5

C500 Spotting Scope

The C500 is both a spotting scope and a 500mm f/8 telephoto lens. Using high-index apochromatic optics and a helicoid focusing system, the C500 focuses down to 7 feet. It uses interchangeable 0.965-inch-diameter eyepieces, with a 25x eyepiece supplied. The hand grip and roof-prism back unscrew for converting the C500 to a camera lens. The 19-ounce C500 is 6.5 inches long. Also available: C300 (15x, 300mm f/5.6) and C1000 (50x, 1000mm f/11).

COSMOS, Ltd., 9215 Waukegan Road, Morton Grove, IL 60053, (800) 643-2351. $295; Carrying case: $24.95. Also available: C300: $249; C1000: $1,495. ☐

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

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UNCONDITIONALLY WARRANTED FOR 5 YEARS AGAINST ANY TYPE OF DAMAGE (Patent #3,897,140).

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Tuthill Solar Skreen® Filters produce high-quality images as shown in photographs in *Sky & Telescope*, October 1991, pages 358 and 440. Recommended by ALPO and used in solar filters sold by CELESTRON INTERNATIONAL. Over 100,000 satisfied users worldwide. Filters come complete with photographic exposure data, information on solar eclipses visible until the year 2030, and guidelines for finding stars and planets in the daytime.

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Video Camcorders/Cameras	$65
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Celestron C8, Ultima 8	$95
Celestron C11, Ultima 11	$145
Celestron C14	$175
Celestron C4.5 Reflector	$75
SF-C8, Comet Catcher	$95
Celestron C90 Spotter	$49
C65, SS80, or 500mm	$75
Astro-Physics 4" Starfire	$75
Astro-Physics 6" Starfire	$120

Meade 2045D, 2045SS	$49
Meade 2080, 8" LX100 or LX200	$95
Meade 2120, 10" LX100 or LX200	$135
Meade 102ED 4" Refractor	$79
Meade 127ED 5" Refractor	$108
Meade 8" Starfinder, 628C	$85
Meade 8" Starfinder, 826C	$95
Meade 10" Starfinder, DS 10A	$115
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Tele Vue Pronto	$69
Tele Vue Genesis	$85
Questar 3.5"	$95

Edmund Astroscan	$75
Criterion Dynamax 8"	$95
Bausch & Lomb 8" SCT	$85
Bausch & Lomb 8" SCT	$95
All other telescopes	CALL

Unmounted Filter Material Only

Less than 4" aperture	$29
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Over 14" aperture	CALL

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GLASS - *TYPE 1* *(Full Aperture)*

Made from high quality hand select glass, machine polished and TRIPLE COATED with a Nickel-Chromium alloy (same as Inconel). Mounted in a machined aluminum cell ready to attach to telescope. Solar image is yellow-orange. No secondary filtering is necessary.

Aperture	Mounted	Aperture	Unmounted
2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

40mm to 80mm Binoculars - Mounted .... $92.00 pr.

GLASS - *TYPE 3* *(Full Aperture)*

Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 & type 2. Type 3 filters are for photographic use only.

Aperture	Mounted	Aperture	Unmounted
2.4"	$79.00	2.4"	$65.00
3.1"	82.00	3.1"	69.00
3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
10"	172.00	10"	152.00
11"	199.00	11"	179.00
12.5" to 13.1"	229.00	12.5" to 13.1"	209.00
14"	259.00	14"	239.00

GLASS - *TYPE 2* *(Full Aperture)*

Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	119.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
14"	199.00	14"	179.00

40mm to 80mm Binoculars - Mounted .... $115.00 pr.

Threaded camera filters also available.

Types 1 & 2 are for unlimited visual use and general photographic use. Instructions included with all filters, including tips on solar photography.

Our filters are many times more durable than common aluminized Mylar. Aluminized plastic cannot hold up to long-term ultraviolet radiation and environmental contaminants as well as Nickel-chrome and stainless steel coated glass. Wrinkled Mylar can cause visual and photographic difficulties, can be easily damaged in handling or if placed on an uneven surface, and is difficult to clean. Also, a light blue solar image does not yield as much detail and contrast.

H-alpha prominence filters now available.
Priced from $675-$785 complete & ready to attach to telescope. Includes free Type 2 white light filter.

If you see a lower price on any copy-cat glass solar filters, call us.

SOLAR ECLIPSE VIEWERS

Mylar

Aluminized on both sides. Mounted in rigid frame. Mylar window: 1-5/8" x 3-1/8". Each filter supplied in individual envelope. Light transmission is blue.
3" x 5" Overall size .... $1.00 ea.

Plastic

Same as Mylar except this filter yields a sharper image with orange transmission
2-5/8" x 4-5/8" Overall size .... $2.00 ea.
Minimum order of 10 eclipse filters in any combination. Please add appropriate shipping/handling. 10 units: $3.00. Plus $1.00 for each additional 10 units. Minimum credit card order of $25.00. Quantity discounts available starting at 100.

Mylar and plastic viewers are coated to a neutral density of 5. Transmission in visual light is approximately 1/1,000th of one percent. There is no significant transmission in ultraviolet or infrared. Designed for naked eye visual use.

Ordering Information:

Solar filters are shipped free in continental U.S. when payment is included with order. Shipping extra on credit card orders ($3-$6 depending on aperture). Payment may be made by personal check, bank check or money order. We also accept **Visa, MasterCard** and **American Express. PLEASE SPECIFY TELESCOPE BRAND AND/OR OUTSIDE DIAMETER MEASUREMENT OF TELESCOPE TUBE.** The cost of the filter is based on the telescope aperture. The mounting cell fits over and around the end of the telescope tube (friction fit). The coating faces the inside. Unmounted filters are the glass only.

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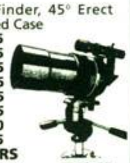

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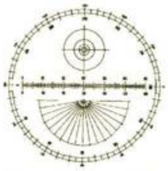

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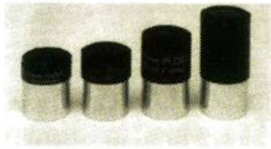

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Satellites and Education Conference IV, West Chester University, West Chester, Pennsylvania. Sponsored by the School of Education, NASA, GE Astro Space, Pennsylvania Space Grant Consortium, and the National Oceanic and Atmospheric Administration of the U. S. Department of Commerce. Contact: Nancy McIntyre, West Chester University, PA 19383. Phone: (215) 436-2323.

March 20
2nd Annual Messier Night, Lake Hudson State Recreational Area, Clayton, Michigan (cloud date: March 27). Sponsored by the Astronomical Societies of Lenawee and Hillsdale Counties. Write to Astronomical Societies of Lenawee and Hillsdale Counties, P.O. Box 229, Hudson, MI 49247. Phone: (517) 448-7173 days or (517) 547-7402 evenings.

April 5-7
Second Solar Astronomy Convention, La Paz, Baja California Sur, Mexico. Sponsored by the La Paz Station of the Solar Astronomy Research Center. Write to Calle La Purisima 119, Colonia Bellavista, Codigo Postal 23050, La Paz, Baja California Sur, Mexico. Phone: 91-682-1-07-32.

April 8-11
Houston Future Fest, Hyatt Regency Downtown, Houston, Texas. The public is welcome at this science fiction convention, but admission to most of the events and activities will require paid registration. Write to Future Fest, P.O. Box 1770, Friendswood, TX 77546-1770. Phone: (800) 787-5317.

April 9-18
Astronomy Week, Cormack Planetarium. Write to Cormack Planetarium, Museum of Natural History, Roger Williams Park, Providence, RI 02907-3600, or call Michael Umbricht (401) 785-9457.

April 10
Northeast Astronomy Forum, Rockland Community College, Suffern, New York (Exit 14B off I-287). Sponsored by the Rockland Astronomy Club. Contact: Don Urban, Rockland Astronomy Club, 73 Haring Street, Closter, NJ 07624.

April 16-17
Mid-South Spring Star Gaze, Rainwater Observatory, French Camp, MIssissippi. Contact: James Hill, FCA, French Camp, MS 39745. Phone: (601) 547-6865 days or (601) 547-6970 evenings.

May 1
Astronomy Day, Groveland, Massachusetts. Activities at several sites. Sponsored by the North Shore Amateur Astronomy Club. Contact: Paul Graveline. Phone: (508) 470-1970.

May 17-23
Texas Star Party, Prude Ranch, near Fort Davis, Texas. Hosted by the Southwest Region of the Astronomical League. Contact: TSP Registrar, 1326 Mistywood Lane, Allen, TX 75002.

May 29-31
40th Anniversary Celebration, Museum of Natural History. Write to Cormack Planetarium, Museum of Natural History, Roger Williams Park, Providence, RI 02907-3600, or call Michael Umbricht (401) 785-9457.

June 11-12
8th Annual Sedona-Verde Valley Astronomy Festival, Red Rock State Park. Contact: Professor Russell Nidley, Director, 1101 Zalesky Road, Cottonwood, AZ 86326. Phone: (602) 634-7332.

June 18-20
1st Annual Star Party, Sola Fide Observatory, Austin, Minnesota. Sponsored by the Cedar River Astronomy Club. Contact: Keith Snyder, 407 15th St. S.E., Austin, MN 55912. Phone: (507) 433-1903.

June 18-20
Jersey Star Quest IV, Beemerville 4-H Camp off Route 519 (near High Point State Park), Sussex, New Jersey. Sponsored by the Amateur Astronomer's Association of Princeton. Contact: Greg Mauro, P.O. Box 2017, Princeton, NJ 08543. Phone: (609) 585-9465

July 29-31
ALCON '93, Sheraton Inn and Conference Center, Madison, Wisconsin. The Madison Astronomical Society will host this 47th annual convention of the Astronomical League. Write to Madison Astronomical Society, ALCON '93, P.O. Box 14747, Madison, WI 53714-0747

August 13-14
Stellafane, Springfield, Vermont. Write to Stellafane, P.O. Box 50, Belmont, MA 02178. ☐

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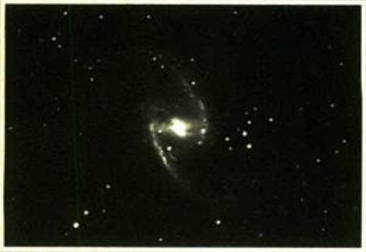

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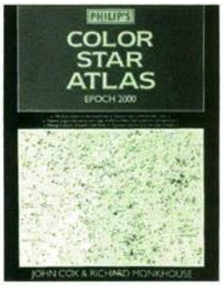

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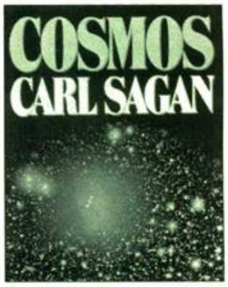

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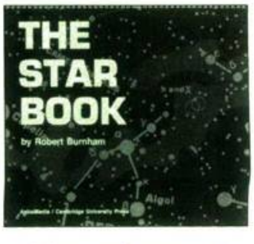

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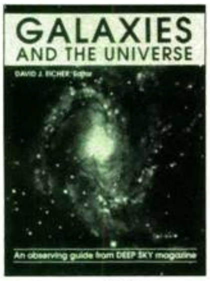
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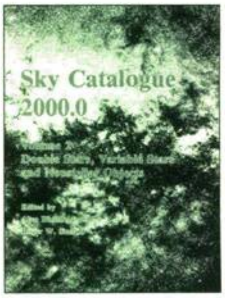

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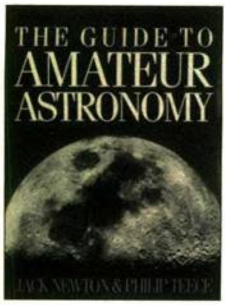

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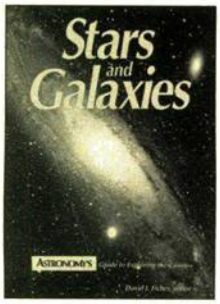

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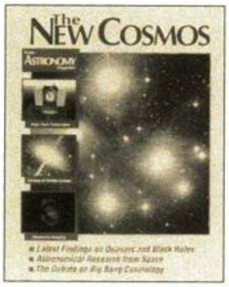

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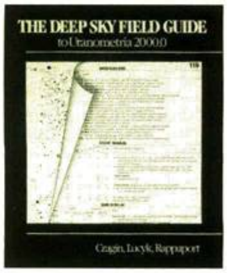

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Toutatis Seen with Radar (page 36)

"Radar Reveals a Double Asteroid," by Steven J. Ostro, ASTRONOMY, April 1990. Reports on the radar observations that revealed 4769 Castalia (1989 PB) as a double asteroid.

Counting to the Edge of the Universe (page 38)

The Big Bang, by Joseph Silk, (W. H. Freeman and Company, 1989). Describes number counts and the use of galaxies as cosmological probes.

Mare Nectaris (page 66)

The Moon: An Observing Guide for Backyard Telescopes, by Michael T. Kitt, (Kalmbach Publishing, 1992). Explains the Moon's real geologic history, then gives a friendly guided tour of the main features visible on the lunar surface using a small telescope.

The Digital Darkroom: "Printing the Image" (page 72)

Choosing and Using a CCD Camera, by Richard Berry, (Willmann-Bell, Inc., 1992). A guide to selecting the right camera for your application as well as detailed instructions for taking images. Includes software for image calibration.

Astronomical Image Processing, by Richard Berry, (Willmann-Bell, Inc., 1991). Image-processing software with manual that explains the basics.

"The Digital Darkroom: 'Developing' the Image," by Richard Berry, ASTRONOMY, March 1993. Tells how to create a calibrated CCD image by taking flat-field and dark frames.

"Going Digital with Color," by Richard Berry, ASTRONOMY, July 1992. An introduction to creating color images from calibrated black-and-white CCD images.

Cover: Tony Hallas and Daphne Mount, 6-inch refractor, hypered Fuji Super HG 400 film, 50-minute exposure; ***p. 4:*** Ken Spencer, 5-inch f/8 refractor, Ektapress 400 film, 30-second exposure; ***p. 18:*** C. R. O'Dell and NASA; ***p. 20:*** NASA; ***p. 21:*** Margaret Kivelson; ***p. 22, bottom left:*** Wilkes Cirker; ***top right:*** George Miley, Kenneth Chambers, Wil van Breugel, and Duccio Macchetto; ***p. 24, left:*** Jeff Hester and NASA; ***top right:*** T. J. Cornwell and J. M. Uson/NRAO; ***bottom right:*** J. MacKenty and NASA; ***pp. 26-28:*** NASA/JPL; ***p. 30:*** Steven G. Davis; ***p. 32:*** Steven G. Davis, NASA/JPL; ***p. 34:*** NASA/JPL; ***pp. 36-37:*** JPL; ***p. 38:*** Sidney Harris; ***p. 39:*** M. Seldner, B.L. Siebers, E.J. Groth, and P.J.E. Peebles; ***pp. 40-41:*** NGC 7331 and Centaurus cluster courtesy National Optical Astronomy Observatories; ***pp. 42-43:*** Hercules and Coronae Borealis clusters courtesy California Institute of Technology; distant galaxies courtesy Anthony Tyson; ***p. 56:*** Jack Newton, 16-inch f/5 reflector, 14-minute exposure using a cola camera; ***p. 57:*** Kim Zussman, modified 11-inch SCT at f/10, hypersensitized Tech Pan film, 140-minute exposure; ***p. 58:*** Martin C. Germano, 8-inch SCT at f/5, 103a-F film, 75-minute exposure; ***p. 59 top:*** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 100-minute exposure; ***bottom:*** Martin C. Germano, 8-inch f/5 reflector, hypersensitized Tech Pan film, 60-minute exposure; ***p. 60:*** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 120-minute exposure; ***p. 61:*** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 90-minute exposure; ***p. 62:*** Kim Zussman, modified 11-inch SCT at f/10, hypersensitized Konica 1600 film, 80-minute exposure; ***p. 63:*** Joe Liddell, 17.5-inch f/4.5 reflector, 3M 400 film, 30-minute exposure; ***p. 67:*** Jean Dragesco; ***p. 68:*** Chris Cook, 8-inch f/10 SCT at f/6.3, 8-minute exposure, Fujicolor Super HG 400 film, November 27; ***p. 69, top left:*** Martin Mobberley, 14-inch f/5 Newtonian, 24-minute exposure, hypered Tech Pan film, November 13; ***top right:*** James Foster, 11-inch f/11 SCT, 56-minute exposure, hypered Tech Pan film, November 27; ***bottom left and right:*** James DeYoung and Richard Schmidt, 24-inch reflector, November 30; ***p. 70, top left:*** Michael Stecker, 8-inch f/4 telescope, 30-minute exposure, hypered Tech Pan film, October 25; ***top right:*** Michael Stecker, 8-inch f/4 telescope, 20-minute exposure, hypered Tech Pan film, October 31; ***middle left:*** Michael Stecker, 8-inch f/4 telescope, 30-minute exposure, hypered Tech Pan film, November 14; ***middle right:*** Michael Stecker, 11-inch f/5.5 telescope, 20-minute exposure, hypered Tech Pan film, November 27; ***bottom:*** James Foster, 11-inch SCT at f/6.3, 53-minute exposure, November 20; ***p. 71:*** Gerald Rhemann, 7-inch Schmidt camera, 18-minute exposure, Ektachrome 100 film, November 24; ***p. 72:*** Jack Newton, 25-inch reflector, ST-6 CCD camera, 5-minute exposure in green light; ***p. 73:*** Darla Gawelski; ***p. 74:*** Jack Newton; ***p. 75:*** Jack Newton, image processing by Richard Berry; ***p. 76:*** Richard Berry; ***p. 77:*** Jack Newton, image processing by Richard Berry; ***p. 87:*** Lunar eclipse by Thomas R. Perry, 8-inch SCT, f/6.3, 40 seconds, Kodacolor 1600; Toutatis by Robert Melvin and Bill Gladson, 24-inch Boller and Chivens Cassegrain telescope, Microluminetics Cryocam CCD camera, 10-second exposures taken at 1-minute intervals, composite by ASTRONOMY; ***p. 88:*** John Rozakis and Nicolas Matsopoulos, 6-inch f/5 reflector, 90 seconds, Kodacolor 100 Gold; Terence Dickinson, 300mm telephoto at f/2.8, 75 seconds, Kodachrome 200; Benjamin Gomes-Casseres, 200mm telephoto with 2x doubler, partial phases 1/2 second at f/64, totality 5 minutes at f/8, Ektachrome 400, drive turned off 1 second every 25 seconds to provide tracking speed closer to lunar rate; Jimmy McGinnis, video taken with Canon L-1 camera; Ralph J. Merletti, 50mm lens, f/1.7, Kodacolor 100 Gold; ***p. 89:*** Paul Shulins, 24mm lens at f/5.6, 23 exposures made at 10-minute intervals starting at 4:50 p.m. Eastern Time, Ektachrome 100

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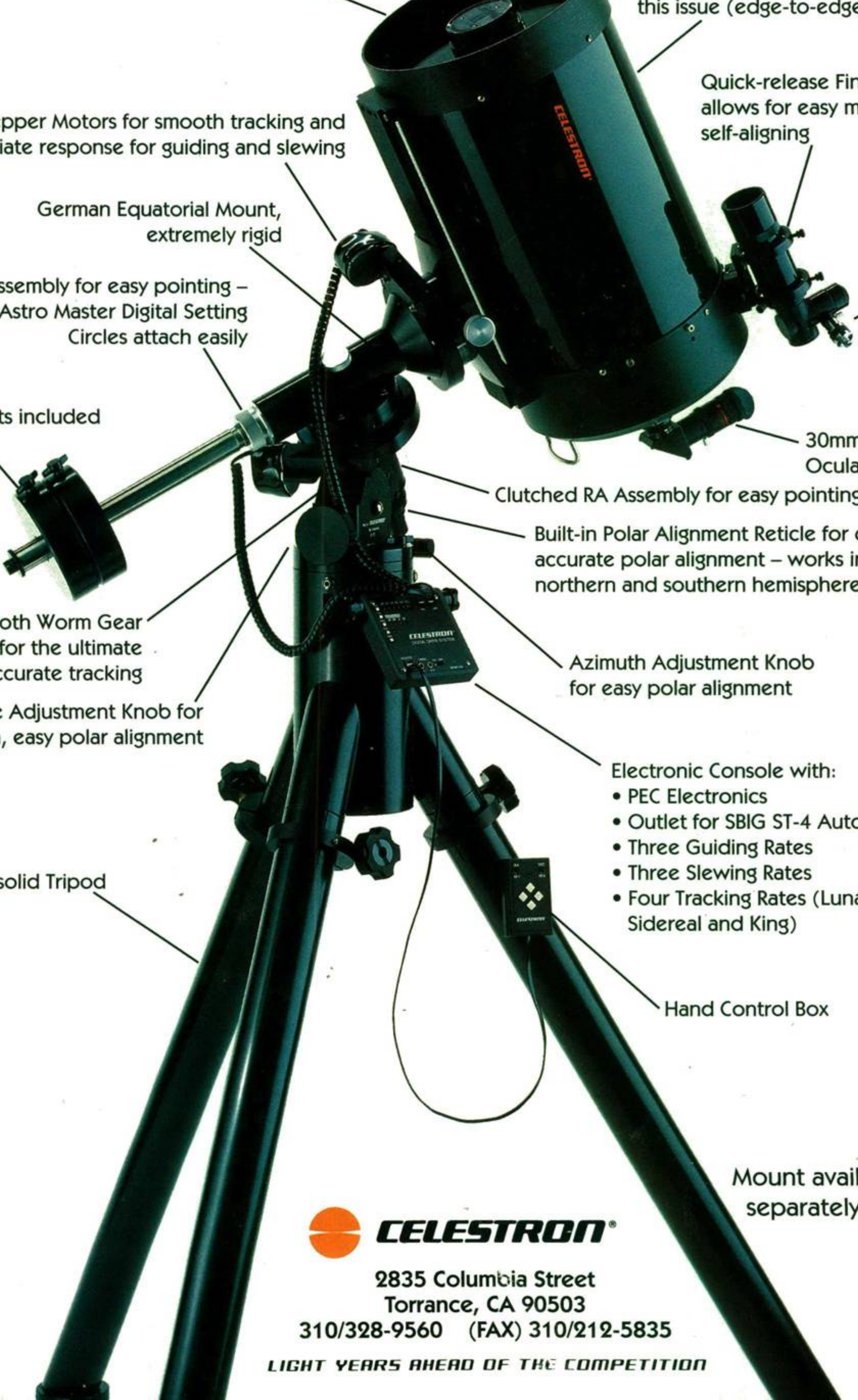

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